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CELIAC DISEASE

RACHFORD MEMORIAL LECTURES

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Celiac disease is a condition in which although there is marked disturbance of function resulting in certain very characteristic symptoms, morbid anatomy cannot produce any explanation. For this reason alone it should prove an interesting subject for discussion, but there is another and more important reason which emboldens me to think that I need not apologize for choosing this disorder as the subject for the first Rachford Memorial Lecture. The outstanding feature in celiac disease is the inability of the child suffering from it properly to absorb fat from the intestine, and remembering the classic researches of Dr. Rachford on the action of pancreatic juice and bile, I cannot help feeling that a review of the present condition of the knowledge of celiac disease would have proved of special interest to him.

Two years before Dr. Rachford started his researches on the bile and pancreatic juice, Samuel Gee wrote a paper entitled "On the Coeliac Affection." This little paper, which occupied less than four pages in the *St. Bartholomew's Hospital Reports* for 1888, vividly describes the clinical picture of celiac disease, and later writers have added little to it so far as the clinical characters of the disease are concerned. It is quite clear, however, that Gee regarded this disorder and sprue as one and the same disease, although he does not refer to the latter by name, because he wrote, "Sometimes from India Englishmen return sick with the coeliac affection: seldom is it met with in adults who have never left our island." There have been others since his day who have held the same view; indeed, at present there are not wanting supporters of the theory, but I think I shall be able to show you that there are no real grounds for such a belief.

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The author's spelling of the word "coeliac" has been changed to "celiac" to conform with the style of the American Medical Association Press.

In the year following Gee's contribution, Gibbons [1] published a paper, "The Coeliac Affection in Children," in which he definitely stated that it is not the same disease as sprue. He probably included some cases of infantile atrophy, for he stated that the majority of sufferers from the disease die; for a like reason I have a suspicion that Gee fell into the same error, because he said, "Death is a common end."

After the publication of these two papers, interest in the disease appears to have lapsed for a long time, because it was not until fourteen years later (1903) that the next paper of any importance appeared. This was written by Cheadle,[2] "On Acholia," and it owes its chief importance to the fact that for the first time the occurrence of an excess of fat in the stools was not only recognized but proved quantitatively by Willcox. Cheadle regarded the disease as due to a cessation of bile secretion, and hence the choice of the title "acholia." From 1902-1915, Bramwell [3] and others published a series of papers on "Pancreatic Infantilism," but there are very good grounds for accepting Miller's statement that at least some of the cases were examples of celiac disease.

Chronologically, the next contribution of importance, after the papers by Gee and Cheadle, was the appearance in 1908, in America, of Herter's monograph on infantilism from chronic intestinal infection.[4] Herter's views will be dealt with later; suffice it now to say that it has been generally accepted that his cases of "intestinal infantilism" were examples of the "celiac disease," although Herter appears genuinely to have rediscovered the disease and to have been unfamiliar with the writings of Gee and Cheadle. One year later, 1909, the first important German contribution appeared. This was a paper by Heubner [5] entitled, "Ueber Schwere Verdauungsinsuffizienz beim Kinde jenseits des Säuglingsalters." This title for the disease is rather long and cumbersome and has been shortened to "Schwere Verdaungsinsuffizienz."

I do not propose to enter at length into the bibliography of this subject, and references will be made to other papers in the course of the lectures, but mention must be made of some of the more important contributions that have appeared since the European War. In this

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1. Gibbons, R. A.: Edinburgh M. J. **35**:321, 1889.
2. Cheadle, W. B.: Lancet **1**:1497, 1903.
3. Bramwell, Byrom: Tr. Med. Chir. Soc. Edinburgh **21**:94, 1901-1902; Clin. Study, Edinburgh, 1903-1904, p. 68; Edinburgh M. J. **1**:323, 1915.
4. Herter, C. A.: On Infantilism from Chronic Intestinal Infection, Characterized by the Overgrowth and Persistence of the Nursling Period, New York, The Macmillan Company, 1908.
5. Heubner, O.: Jahrb. f. Kinderh. **70**:667, 1909.

category I include Still's Lumleian Lectures in 1918,[6] the papers by Howland [7] and Miller [8] and the monographs of Lehndorff and Mautner [9] and of Fanconi.[10]

TERMINOLOGY

From this short historical introduction it is obvious that celiac disease has been described under differing headings; thus, there is "celiac affection," "acholia," "intestinal infantilism" and "Schwere Verdauungsinsuffizienz." In addition to these, it has been spoken of as "celiac infantilism" and in America as "chronic intestinal indigestion," a term that may be regarded as the English version of Heubner's title. The majority of cases described as chronic intestinal indigestion cannot rightly be regarded as celiac disease, and therefore, unless the prefix severe is used, the name is unsatisfactory. Other labels used to designate the condition on the Continent of Europe are "Die Coeliakie," "Heubner-Herter disease" and "Gee-Herter disease."

There are many objections to attaching the name of any person to a disease, not the least of which is that the same person may have his name attached to more than one; thus, for instance, one now has to speak of von Recklinghausen's disease of nerves and von Recklinghausen's disease of bone. This form of nomenclature is a variety of hero worship which is gratifying to the worshippers and sometimes to the hero, but is the cause of much confusion for every one else; for although it may commemorate a historic fact, it does not convey any hint as to the character of the disease of which it is the label. If, in spite of all such objections, it is desired to attach the name of a person to the particular disease under consideration, I plead for historical accuracy and for the right direction of the hero worship, and that it should be called "Gee's disease"; yet I cannot help feeling that Gee himself would have preferred that the name should be "the celiac affection or disorder or disease," and that, because of the derivation of the word from the Greek, he would have preferred it spelled "coeliac" instead of "celiac." Morse [11] has adversely criticized the term celiac disease, and said that if it is used to denote a single disease or symptom complex it is irrational, because the definition of "celiac" is relating to the abdomen or to the cavity of the abdomen" and therefore applies equally

6. Still, G. F.: Lancet **2**:163, 1918.

7. Howland, J.: Tr. Am. Pediat. Soc. **33**:11, 1921.

8. Miller, Reginald: Lancet **1**:743, 1921; **2**:1099, 1923; **1**:330, 1926; Brit. J. Child. Dis. **20**:88, 1923; Arch. Dis. Childhood **2**:189, 1927.

9. Lehndorff, H., and Mautner, H.: Ergeb. d. inn. Med. u. Kinderh. **31**:456, 1927.

10. Fanconi, A.: Die intestinale Infantilismus und ähnliche Formen der chronischen Verdauungsstörung, Berlin, S. Karger, 1928.

11. Morse, J. L.: New England J. Med. **204**:668, 1931.

well to appendicitis and tuberculous peritonitis. It does, however, draw attention to the fact that the abdominal symptoms of the disease are prominent without committing the user to any theory of causation.

CLINICAL FEATURES

Celiac disease is no respecter of persons, its victims being found in all grades of society, although in my experience it is found more frequently in hospital than in private practice, a point that distinguishes it from ordinary chronic intestinal indigestion in which the converse obtains. It has never been seen in an infant at the breast. Girls are more frequently attacked than boys; it has been known to occur in one and both homologous twins, and also in more than one instance in sisters and cousins, but there is no real evidence of any familial predisposition. The geographic distribution of the disease is interesting. Most of the cases have been observed in England and America; next in order come Germany and Austria, while others have been recorded in Scandinavia, Switzerland and Holland. In France, the condition is rare, and only a few cases have been described in Italy. A point of importance with regard to the supposed relationship to sprue is that no case of celiac disease has so far been reported from India.

The disorder is somewhat of a rarity; thus, until the end of 1918 Still had seen only seventeen cases among 14,800 hospital patients, but had seen twenty-four in his private practice, an experience contrary to my own. Since 1920, seventy-three cases have come under our observation in Birmingham and we have exact follow-up records of from three to six years' duration in over forty instances; in addition to these, through the kindness of Dr. Kenneth Blackfan, my colleague, A. V. Neale, was allowed to investigate and use the records of twenty-one cases seen at the Boston Children's Hospital. The remarks I have to make are therefore based on a study of ninety-four cases. Some idea of the frequency of the disease may be gained when I say that in the same decade a hundred patients with "pink disease" were admitted to the hospital. I think there can be no doubt that celiac disease is more common than these statistics represent and that the number of cases, particularly of the less severe varieties, will increase with the dissemination of knowledge regarding it. Leonard Findlay tells a tale of a visit paid by Sir William Gairdner, a late professor of medicine at Glasgow University, to Charcot's clinic at Paris. After Charcot had shown him a specimen of "Charcot's joint," Gairdner said that he had never seen such a complication, and that tabes in France must be a very different disease from tabes in Scotland, because he could not have failed to observe such a condition had it existed. Charcot's reply was, "Oh, we only see what we look for. You go home and look." Gairdner went

home, looked and found, and I feel sure that such will be the experience of those who look for celiac disease. In England, during the late European War, celiac disease was put on the schedule of diseases for which extra meat might be obtained. "Under these circumstances," wrote Miller, "the disease emerged from its obscurity and attained a wide popularity, so much so that its name was removed and, it being debased from its exalted position, there subsided what was probably the only epidemic of the complaint which will ever have an existence even on paper." There is therefore something to be said for dealing, as I propose to do, only with cases that have come under observation since the war.

The onset is usually insidious and occurs between the age of 9 months and 2 years, a period of life that is associated with dietetic changes and dentition, and hence the early digestive symptoms are not infrequently ascribed to these causes. It is therefore often only after the bowel disorder and failure to thrive have been present for some time and become really obvious that the correct diagnosis is made, or even that medical advice is sought. In the early stages of the illness the patient loses his appetite and does not thrive; looseness of the bowels and often vomiting occur, and there may be some alteration in disposition. At this stage it is almost impossible to make a diagnosis of celiac disease, and indeed the condition is often undiagnosed until the complete clinical picture has developed; thus the real cause of the child's illness frequently remains unsuspected until the child is 5 or 6 years old. Careful inquiry into the history of such cases will nevertheless often reveal the fact that digestive disturbances have been present for a long time, possibly for years. In at least two instances the disease has developed in babies that I have had in the hospital for nutritional disorders, and it was not until they had been in the hospital some weeks that the passage of pale stools and the child's failure to thrive aroused suspicions of what proved to be the correct diagnosis. In one instance the child was admitted when 11 months old for rickets and malnutrition; the rickets healed in the normal period, but six weeks later she showed signs of a catarrhal condition of the chest; the abdomen became distended, and it was noticed that the stools were pale. A chemical examination of the latter showed the findings characteristic of celiac disease. Although the insidious onset is the more common, occasionally the development of the disease appears to occur abruptly, and in such instances a few days after the child has developed an acute attack of diarrhea and vomiting the stools are noticed to be large and pale.

The typical clinical picture of celiac disease may perhaps best be described if I use some of Gee's descriptions as a basis, and although I shall use his actual words, I shall sometimes alter the order in which he deals with different symptoms. The quotations are, I think, inter-

esting, apart from their singular graphic character, in that they reveal a style of writing and phraseology now seldom used, and their curious staccato character is of interest because I am told that such was also the manner of his speech.

> The coeliac disease is commonest in patients between one and five years old: it often begins during the second year of life. The onset is usually gradual so that it is hard to fix: sometimes the complaint sets in suddenly like an accidental diarrhoea. Diarrhoea alba is a name employed in India to denote the coeliac affection; not that it is always a coeliac flux, a diarrhoea strictly speaking. True the dejections are faecal, more liquid and larger than natural but they are not always more frequent than natural; it may be that the patient voids daily but one large, loose, whitish stinking stool.
>
> The patient wastes more in the limbs than in the face which often remains plump until death is nigh. Muscular weakness great: muscular tenderness often present. While the disease is active children cease to grow. Cachexia a fault of sanguification betoken by pallor and a tendency to dropsy is a constant symptom: the patients become white and puffy.
>
> The belly is mostly soft and doughy and inelastic: sometimes distended and rather tight. Wind may be troublesome and very foetid. Appetite for food differs in different cases, being good or ravenous or bad.
>
> To diarrhoea alba add emaciation and cachexia and we have a complete picture of the disease.

Thus spoke Samuel Gee, and to adapt your John Greenleaf Whittier:

> Are we so much wiser grown
> That we cannot in our day
> Make his words our own?

I think not. Certainly it is true that whenever people believe that they have discovered some new fact in celiac disease, a reference to this classic clinical cameo has a chastening effect, for, time after time, they will find that their discovery has been forestalled. If some of these quotations from Gee are borne in mind, the truth of that statement will become obvious as the various clinical manifestations of the disorder are discussed.

The characteristics of the fully developed case of celiac disorder are as follows:

1. The passage of large, pale and offensive stools containing considerable amounts of split fat.
2. Wasting, which may reach an extreme degree.
3. Abdominal distention.
4. Severe stunting of growth amounting to infantilism.
5. Anorexia and certain other nervous symptoms.
6. The not infrequent presence of "deficiency" symptoms.

Characters of the Feces.—The feces furnish the key to the diagnosis of this condition, and no one has described their characteristics better, indeed, none so well, as Gee.

Signs of the disease are yielded by the faeces; being loose not formed but not watery: more bulky than the food taken would seem to account for: pale in colour as if devoid of bile: yeasty, frothy, an appearance probably due to fermentation; stinking, stench often very great. The pale loose stool looks very much like oatmeal porridge or gruel. The hue is somewhile more drab, other while more yellow.

This is an excellent description of the typical stool, and the comparison of their appearance to that of oatmeal porridge is very apposite and striking. The stool also frequently has a curious shimmer and looks as if the porridge had received a coat of aluminum paint. In the long drawn out course of celiac disease there are many ups and downs, and it is usually only in the latter, which are due either to inadequate treatment, indiscretions in diet, parenteral infections or the natural history of the disorder that these typical stools occur; whereas in the periods of improvement, which are sometimes quite lengthy, the stool may be formed, even colored, and indeed the patient may actually become constipated. For this reason, Miller held that the stress laid on diarrhea alba as the diagnostic sign of celiac disease is a mistake. Miller was also of the opinion that certain cases of celiac disease run their entire course without diarrhea and spoke of the nondiarrheic and classic (diarrheic) type of celiac disease. Such a division seems unnecessary, for, since the classic type has nondiarrheal as well as diarrheal phases, it would appear that the real difference between the two types is only one of the degree of severity of the disorder. The number of stools passed each day is variable; in the diarrheal phases, two or three is a very common number, although there may be as many as five or six, whereas in the nondiarrheal phases there may be only one or two a day. The stool is a large one, although the bulk may vary considerably from day to day. Some of the vagaries of the patient's weight chart, which are such a marked feature of the course of the disease, may depend on the weight of the stools since the total weight of stools passed in twenty-four hours may be 1 pound (453.6 Gm.), and this in a child whose weight may not exceed 20 to 30 pounds (9,000 to 14,600 Gm.) The frothy, yeasty appearance on which Gee comments is quite frequently seen, and his explanation that it is due to fermentation is probably correct, the cause probably being the fermentation of carbohydrates, since increasing the carbohydrate content of the food produces an increase in this frothy appearance. According to Morse, in America, this fermenting, frothy stool is nowadays more commonly seen than the "aluminum paint porridge" variety, a reversal of the previous experience. The stools also sometimes show an excess of mucus and in the diarrheal periods even streaks of blood, but these characters are probably the result of enteral or parenteral infections to which these children are so prone and in no real sense of the word peculiar to, or symptoms of, celiac disease.

If the stool is loose, it shows a high percentage of water, a point stressed by some Continental writers and thought by them to show a defective absorption of water—although it may, of course, be due to dehydration—and this accounts for the marked thirst that some of the patients exhibit. This hydrolability is, according to Fanconi, a constant and characteristic sign of the disease. On the ordinary diet, the stool always, even in the nondiarrheal periods, contains a considerably greater amount of solid matter than is normal, and of this solid matter a large proportion is fat. The dried feces of a normal child on an ordinary mixed diet should not contain more than 25 per cent of fat,

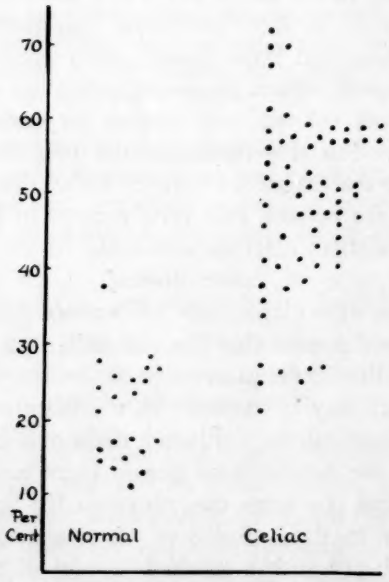

Chart 1.—Percentage of fat in dried feces of normal children and of those suffering from celiac disease when on an ordinary mixed dietary.

but in celiac disease on such a diet fat forms usually from 40 to 60, and may even reach 80, per cent of the dried feces (see chart 1).

In making a diagnosis of celiac disease, an estimation of the percentage amount of fat present in the feces is of the greatest importance, but in weighing up the evidence it must always be correlated with the weight of the stool, because in all diarrheal conditions the percentage of fat in the stools is increased. The diagnosis of celiac disease must not be made in any child unless the stool contains more than 2 Gm. of fat daily, and indeed that figure errs on the small side because the amount passed daily is usually very much greater and may reach 20 Gm. or even more. Further, it is always advisable to estimate the amount passed

over a period of from three to five successive days because of the fact, to which attention has already been drawn, that the size of the stool may vary considerably from day to day (chart 2). In spite of the passage of these large amounts of fat in the stools there is no defect in fat splitting, for the neutral fat does not form more than the normal 25 per cent of the total fat content (chart 3). There is some variation in the chemical composition of the stools in the different phases of the disease, fatty acids predominating in the stools of the diarrheal periods and soaps in the more or less formed stools of the nondiarrheal periods. Finally, there is an excessive loss of salts in the stools, particularly of calcium and phosphorus.

Wasting.—As the disease develops, wasting, which is largely due to the absence of subcutaneous fat, becomes obvious and often reaches an extreme degree. The wasting is most marked in the limbs and is particularly noticeable in the gluteal and adductor regions where the redundant skin is creased and may hang down in loose folds. Except in very advanced cases, and sometimes even in these, the face often remains plump and rounded. The cheeks also not infrequently retain quite a degree of color, while the rest of the face has that semitransparency so often associated with a secondary anemia. These factors—the plump and rounded face, the color in the cheeks, the transparency of the surrounding skin, the rather shining, sometimes bluish, sclerotics—combine to produce a facies that is almost characteristic and that becomes even more so when contrasted with the stunted growth of the body. If when first seen the child is clothed, the degree of wasting revealed by undressing is often astounding, for stripping reveals a strange condition. When the child is undressed, two contrasts are obvious: to one, I have already referred—the contrast of wasted limbs and plump face; the other is the striking contrast between the wasting of the buttocks and the distended abdomen. Miller was of the opinion that this wasting of the buttocks is one of the important signs in the diagnosis of celiac disease and said that it is more marked than in any other form of intestinal toxemia in childhood. In severe cases, he described the buttocks as being completely flattened, so that the thighs appear to be set into the trunk like the wooden limbs of a toy. While the "gluteal sign" is frequent in celiac disease, I believe that it may also occur in other wasting diseases, but what is I believe almost if not quite characteristic of the disease is the arresting contrast between the flattened wasted buttocks and the abdominal distention.

The extreme degree of wasting may perhaps be realized when it is stated that a child of 2 may weigh half or even less than half of its normal weight of 28 pounds (12,700 Gm.). The weight chart of a child with celiac disease shows many ups and downs which may corre-

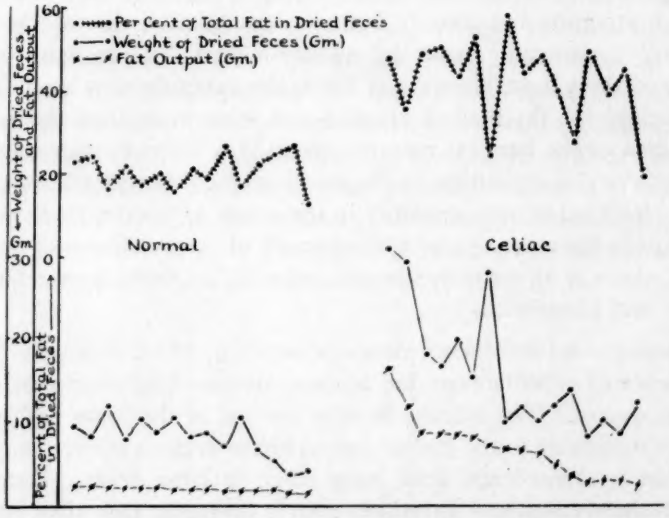

Chart 2.—Percentage of fat in the dried feces, the weight of the dried feces and the weight of fat in the feces in a series of normal children and of those with celiac disease.

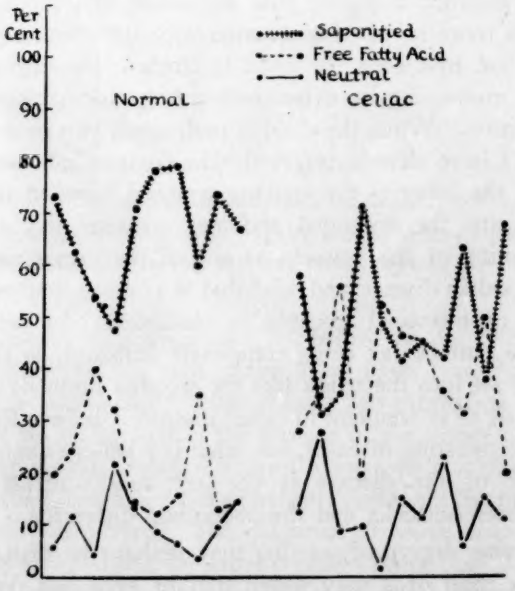

Chart 3.—Amounts of free fatty acids, saponified and neutral fat expressed as percentages of total fat in the feces of a series of normal children and of those with celiac disease.

spond with similar periods in its general well being. These variations are due to some extent to the presence or absence of large amounts of fecal matter in the bowel, to varying degrees of water in the tissues (hydrolability) or to parenteral or enteral infections; thus, the result of many weeks of treatment may be represented by a net gain in weight of only 1 or 2 pounds (453.6 or 907.2 Gm.). Gee obviously recognized the importance of wasting as a symptom or he would not have written, "To diarrhoea alba add emaciation and cachexia and we have a complete picture of the disease."

Abdominal Distention.—Associated with this severe wasting is a considerable degree of hypotonia, the muscles being soft and flabby, and this is a factor in another obvious and characteristic symptom—abdominal distention. This distention is, of course, rendered much the more obvious by the gluteal atrophy and by the general wasting of the thorax and limbs. The distention varies somewhat in degree, depending on the state and contents of the bowel, for roentgenographic examination has shown that the symptom is largely due to the large fluid contents of the small intestine and to flatulent distention, particularly of the colon, which may reach a considerable size. The factors involved, hypotonia of the abdominal wall, hypotonia of the intestinal wall and increase of gas in the intestine, are not dissimilar to those concerned with the enlarged abdomen of rickets. The hypotonia may, therefore, possibly be a deficiency symptom. It is regarded by Fanconi as another of the diagnostic criteria of the celiac disorder, and in his view is due to demineralization, especially to hypophosphatemia. The significance of this hypophosphatemia will be discussed later, but it certainly does not rule out the possibility of the hypotonia being a deficiency symptom. To the examiner's hand the abdomen has a "doughy" feel; the skin is soft and never presents that harsh, dry, granular appearance and feel which to my mind is so very characteristic of abdominal tuberculosis. Nevertheless, this abdominal distention, together with obvious ill health and some diarrhea, frequently leads the parents and too often the doctor to make a diagnosis of "consumption of the bowels."

Retardation of Growth and Development.—The retardation of growth may be the symptom that first arouses suspicion of the true nature of the illness from which the child is suffering, for with the establishment of celiac symptoms of any degree of severity there is a marked diminution in the rate, or even an arrest, of growth and physical development. Conversely, it can be accepted as an axiom that any child who is growing rapidly cannot be suffering from untreated celiac disease. As a result of this retardation of growth, the child, as the years pass, is seen to be stunted; thus, a child of 9 years may appear to be 4 or 5 years younger than its actual age, or the disparity may be

even greater, and unless appropriate treatment is instituted this infantilism becomes more and more marked as the child's age increases. The most extreme case in my experience was that of a girl whose height at 17 years was no greater than that of a normal child of 4 years of age, who showed no sign of secondary sexual characteristics, and whose dentition was so delayed that none of her permanent teeth had erupted. Both dentition and puberty may be, and often are, delayed, but not usually to this extreme degree.

Of course, this symptom was not overlooked by Gee, for he remarked, "While the disease is active children cease to grow; even when it tends slowly to recovery they are left frail and stunted;" but it is to Herter that one owes the recognition of the importance of infantilism as a symptom and hence the frequent use of his phrase "intestinal infantilism" to denote celiac disease.

Nervous Symptoms.—Anorexia may reach an extreme degree; indeed, there is only one other disease in childhood—pink disease—that shows a comparable degree of anorexia. In both these disorders the appetite is not only markedly capricious, but sometimes what appears to be a real loathing for food develops. This loss of appetite has been attributed to a deficiency of vitamin B, but Morse pointed out that the connection between anorexia and a deficiency of vitamin B is far from proved, and he expressed the belief that it is much more likely to be due to gastric and intestinal stasis as emphasized by Fanconi. Fortunately, under treatment, the appetite improves, and it is really remarkable how some children with celiac disease will submit to the infliction of protein skimmed milk as their sole article of diet for weeks or even months.

The behavior characteristics of these patients furnish a most interesting, if somewhat exasperating, subject for study. Their intelligence is normal, although the education of the older children naturally has suffered; the latter indeed often appear to be somewhat precocious, because their infantilism causes them to be treated as much younger than their actual age; or, to put it another way, their mental ability is usually "far in advance of their physical powers." In their periods of improvement the subjects of celiac disease are most attractive, although perhaps rather more easily moved to tears than a normal child, and usually somewhat spoilt; but in the diarrheal periods they are moody, irritable and passionate, and their tempers are as capricious as their appetites. Nothing pleases them, and their misery reaches such a degree that they become a trial to those who have charge of them; one would not suppose them to be the same children who were previously so fascinating. "When they are good, they are very good; but when they are bad, they are horrid." One writer said:

Taken as a whole, the coeliac child is an introspective, hysterical and unhappy child until proper treatment is adopted. In every way that a little child can become a source of misery to itself and to all round it the coeliac child excels. It is so hysterical that no one knows if its complaints are true or false; it is so ill-humoured that it tries the most loving parent; it is so timid that it is a horror to its doctor; and yet withal it has well marked the bullying attributes of the invalid.

This is an excellent description of the untreated child or one who is passing through a diarrheal stage, but it does not do justice to the attractiveness of a child whose general condition is improving.

There is no definite evidence of organic changes in the nervous system. The occurrence of tetany and convulsions and the possibility that some patients develop infantile beriberi will be dealt with under deficiency symptoms. Not infrequently children with celiac disease complain of pains in the legs and difficulty in walking, and sometimes they are unable even to sit up. Some of this is due to weakness from muscular atrophy, but sometimes also there is tenderness of the limbs, to which Gee drew attention in the words "muscular tenderness often present." These symptoms had been regarded as peripheral neuritis even before the suggestion of beriberi was made, and the fact that the knee jerks are often absent is evidence in support of that diagnosis, but it is more than probable that the tenderness is actually the result of scorbutic changes.

Deficiency Symptoms.—Many of the more interesting manifestations and problems of celiac disease fall for discussion under this head. It is clear that if there is some impairment of absorption from the bowel, of which I believe I can give evidence, there may be some deficiency in vitamin absorption, particularly of the fat-soluble vitamins. Recently, Rowntree,[12] using a biologic method of analysis, showed that a marked loss of vitamin A occurs in the feces, and the results of the experiments led her to the conclusion that the loss of vitamin runs parallel with the loss of fat. Before starting on a detailed consideration of the deficiency symptoms, I should like to quote some words of warning from a recent article by Weech.[13]

The diet of the experimental animal is chosen with meticulous care: that of the human being is dictated by geographical location, class or racial custom and the exigencies of economy. A diet so limited as to be deficient in one essential is liable to be defective in several. It is true that the resulting disease may be dominated by symptoms pointing to the absence of one definite constituent, but it must be emphasized that the greatest care is necessary in interpreting minor symptoms as due to the same deficiency that causes the major one merely because they appear concomitantly in the same patient or even in a group of patients.

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12. Rowntree, Jennie I.: J. Nutrition **3**:265, 1930.

13. Weech, A. A.: Association of Keratomalacia with Other Deficiency Diseases, Am. J. Dis. Child. **39**:1153 (June) 1930.

These are words of wisdom which are peculiarly applicable to celiac disease, because in it the effect of defective absorption, which may turn an otherwise efficient diet into a defective one, has to be considered, and furthermore the degree of such malabsorption probably varies from time to time.

Vitamin A.—The work of Bloch,[14] of Copenhagen, on the clinical aspects of vitamin A deficiency, particularly in relation to ocular disorders, is now well known and is about as perfect a bit of research in experimental medicine as could be desired. In his earlier papers, Bloch maintained that this deficiency produced three main symptoms: (1) an interruption in growth, (2) xerophthalmia and (3) a decline in immunity to infections.

Infantilism.—It is now, I believe, generally accepted that vitamin A is not *the* growth vitamin, but that a diminution in the rate of growth occurs as the result of deprivation of any one of the vitamins; for this reason it is not clear whether the stunting of growth in celiac disease is a manifestation of deficiency of any one particular vitamin, or indeed whether it is a deficiency symptom at all. Bloch himself held the view that the infantilism is unlikely to be due to absence of vitamin A, because he found that a concentrate of that vitamin administered subcutaneously had no effect on it. The concentrate he used contained from twenty to thirty times as much vitamin A as cod liver oil; when given in three cases of celiac disease, it produced no result. In Bloch's words, "A case with a deficiency of vitamin A would have shown a pronounced reaction to so many injections."

Xerophthalmia is regarded as the specific lesion of vitamin A deficiency, but, so far as my reading of the literature goes, its presence in celiac disease has been recorded only once (Schick[15]), an interesting contrast to the numerous examples of celiac disease complicated by rickets that have been reported. On the other hand, both Bloch and Wagner[16] have reported xerophthalmia in connection with prolonged jaundice even when the diet contained an adequate amount of vitamin A. One of Bloch's cases is of interest as showing the effect of growth on the production of rickets—a point to which reference will be made later—and this particular case seems to show that deficiency in vitamin A had a more deleterious effect on growth than deficiency of the antirachitic vitamin. There is some explanation of the fact that xeroph-

14. Bloch, C. E.: Further Clinical Investigations Into the Diseases Arising in Consequence of a Deficiency in the Fat-Soluble A Factor, Am. J. Dis. Child. **28**:659 (Dec.) 1924; Acta paediat. **7**:207, 1928.

15. Schick, Belá, in discussion on Haas, S. V.: Beriberi in Late Infancy; the Result of Celiac Disease, Am. J. Dis. Child. **37**:1111 (May) 1929.

16. Wagner, R.: Wien. med. Wchnschr. **74**:1108, 1924.

thalmia is more likely to occur in cases showing prolonged jaundice than in celiac disease, because, as I shall show you, the fat absorption, poor though it may be in celiac disease, is yet incomparably better than in jaundice; but why a child with celiac disease should show rachitic changes to an extreme degree and not xerophthalmia is to me inexplicable. A possible explanation may, however, be inferred from the results of feeding experiments on rats in which xerophthalmia has been found to develop on a diet defective in vitamin A but containing proteins of poor quality more rapidly than on one containing proteins of good value, because in celiac disease there is usually little fault to be found with the absorption of proteins.

The other manifestation of vitamin A deficiency, namely, a liability to contract infection, has recently been emphasized by Mellanby.[17] Bloch declared that in celiac disease there is not "a decline in immunity," but I cannot accept that view, because in my experience these children have shown a peculiar liability to contract infections, particularly coryza and parenteral infective diarrhea. Such symptoms may indeed well be the result of a defective absorption of vitamin A, if Mellanby's view that it is the anti-infective vitamin is correct. Nevertheless, it is significant that Spence,[18] who has recently studied an outbreak of xerophthalmia and night-blindness among the children of the distressed population of the Tyneside, found that there was no evidence of a lowered resistance to general infection among the people living on the xerophthalmia-producing diet. He did find, however, that there was a high incidence of skin sepsis which, together with an increase of epithelial cells in the urine, reacted to treatment with the xerophthalmia-curing substance. These observations afford clinical confirmation of the view of Wolbach and Howe [19] that the specific tissue change in vitamin A is a debasement and damage of epithelial structures, and certainly some cases of celiac disease do show marked evidence of skin sepsis. One other point of interest was that these children of Tyneside generally showed no alteration in growth.

Vitamin B.—Edema is frequently seen in celiac disease, and occasionally free fluid can be demonstrated in the abdominal cavity, a symptom that adds yet another difficulty to its differentiation from tuberculous peritonitis. This edema is very similar to the nutritional or hunger edema sometimes observed in marasmatic infants and seen particularly among children in Vienna during the late war, and may be an expression

17. Mellanby, E.: Brit. M. J. **1**:677, 1930.

18. Spence, J. C.: Arch. Dis. Childhood **6**:17, 1931.

19. Wolbach, S. B., and Howe, P. R.: Proc. Soc. Exper. Biol. & Med. **22**:402, 1924-1925.

of abnormal water metabolism. Haas,[20] however, suggested that the edema and certain other symptoms are really manifestations of beriberi and due to the inability of the child "to utilize carbohydrates which are the chief carriers of vitamin B." According to this writer, some of the severer cases of celiac disease show all the classic symptoms of beriberi, "edema, pallor, dyspnea, cardiac dilatation, paresthesias, weakness, irritability and paralyses." He found the response to the addition of vitamin B to the diet in the form of banana prompt and striking, and similar to the response to appropriate treatment in beriberi, the depression, asthenia, edema and oliguria clearing up at once. I believe there is a great deal to be said in favor of this view and, with others, I have seen cases in which the edema has cleared up rapidly with the addition of ripe banana to the diet, but I have not personally observed cardiac dilatation, paresthesias or real paralyses. The occurrence of generalized edema in association with diarrhea has been noted many times, and according to Weech it is most probable that diarrhea can act as an inciting cause of a previously latent nutritional disorder. This does not imply that the edema is not a manifestation of vitamin B deficiency, but only that such is more likely to occur when diarrhea is present, and as a matter of fact it has happened in my experience that edema has been observed in celiac disease only in a diarrheal phase.

There is no reference in the literature to the occurrence of any symptoms in celiac disease resembling pellagra.

Vitamin C.—Scurvy is a frequent complication and has been seen by every one who has had charge of any number of cases of celiac disease. The scorbutic manifestations are not usually severe but may produce, in addition to skin manifestations, pains in the limbs, pseudoparalysis, swellings in the neighborhood of the joints and sometimes, as in advanced infantile scurvy, blood in the stools and urine. On occasions, symptoms occur that may not arouse any suspicions of scurvy; thus, recently a child who was doing well began to lose weight rapidly and became apathetic; the stools increased a little in number and greatly in offensiveness, and the condition of the child gave cause for great anxiety. After these symptoms had lasted for a few days and appearances suggested that the illness was likely to be fatal, it was noticed that the gums, although not spongy, were bleeding a little. Inquiry revealed the fact that for some reason the child had not been given fruit juice for some little time, and the addition of orange juice to the dietary resulted in a dramatic recovery. At other times roentgenographic examination will furnish evidence of scurvy when it has not been suspected clinically.

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20. Haas, S. V.: Beriberi in Late Infancy; the Result of Celiac Disease, Am. J. Dis. Child. **37**:1111 (May) 1929.

Vitamin D.—The other deficiency disorder that is universally accepted as of common occurrence in celiac disease is tetany; thus attacks of carpopedal spasm with increased muscular irritability may occur from time to time, and in some instances convulsions have been recorded. The cause of these symptoms is the low concentration of ionic calcium in the blood resulting from the loss of calcium in the form of calcium soaps in the feces and the poor absorption of calcium from the bowel consequent on the impaired absorption of fat and vitamin D. But of all the manifestations of deficiency diseases to which the child with celiac disease is heir, the most interesting are those concerned with the bones. Rickets occurs at two definite periods; in infancy and in the later years of childhood. It may occur at the ordinary age incidence of rickets—6 to 18 months—heal, and reappear at from 5 to 9 years, and may then reach an extreme degree. I have not observed this sequence of events, although it has been reported by Lehmann,[21] but I have seen rickets at these two age periods in different children. The early rickets differs in no way from ordinary infantile rickets and probably arises, as A. F. Hess [22] suggested, before the celiac disease has developed to any marked degree. This early rickets may be cured by irradiation, or by the administration of viosterol in solid form. The complete development of celiac disease may itself produce a cure, for this spells starvation and an arrest of growth, conditions that are known to cure experimental rickets in rats.

There are conflicting reports as to the presence and frequency of the late rickets in celiac disease; thus, Still regarded it as a "remarkable fact that rickets is rarely found. Marriott [23] wrote, "Severe rickets is rarely observed"; A. F. Hess that, "My own experience has been that it is generally absent: in two instances it was evident in slight degree," and in the opinion of Lehndorff and Mauter, rachitic bone changes do not occur at all frequently. On the other hand, J. H. Hess is reported as saying that rickets was demonstrable in most of his cases, and a considerable number of examples have been seen in Birmingham. Finally, there are those who admit the presence of late rickets in celiac disease but regard it as a coincidence and not as due to the latter disorder. The frequency of rickets in celiac disease may depend to some extent on locality, for since we have been looking out for this symptom, that is, from 1925 onward, thirteen cases have been seen in Birmingham, whereas Neale was able to find only one in his series of twenty-one cases in Boston, and Miller informs me that he rarely sees rickets associated

21. Lehmann, F.: Monatschr. f. Kinderh. **30**:124, 1925.

22. Hess, A. F.: Rickets, Including Osteomalacia and Tetany, Philadelphia, Lea & Febiger, 1929.

23. Marriott, W. F., in Abt: Pediatrics, Philadelphia, W. B. Saunders Company, 1924, vol. 3, p. 386.

with celiac disease in children in London. In view of such marked divergence of opinion, it may be of some interest if I recapitulate the steps that lead to the conclusion that the late bone changes in celiac disease were rachitic in nature.

Although McCrudden and Fales,[24] in 1912, described osteoporosis, fragility of bones and fractures in a 10 year old child with celiac disease, I demonstrated in 1913 [25] what I believed to be the first case on record of rickets in celiac disease, and at the same time expressed opinion that rickets was not an uncommon complication of celiac disease. Looking back on that statement, I fail completely to remember what grounds I had to substantiate it; certainly I did not recognize the serious and progressive nature of the condition until it was impressed on me by a case, the history of which I am about to relate, and if I were quite honest I believe I should have to say that I have forgotten my observation of 1913.

M. R., a girl, was first seen in September, 1919; she was then 5 years of age and found to be suffering from celiac disease. She was placed on a "fat-free dietary" and given bile salts by mouth. The intestinal symptoms improved, but in January, 1921, she developed the first of several attacks of tetany, and in May, 1922, knock-knee was noticed. From this time onward, despite splinting, the deformity increased, and eventually, in 1923, walking became impossible, although there was considerable improvement in her general condition. Clinically, the bone changes were recognized as being rachitic, but treatment seemed impossible if a fat-free diet was to be continued. It was not until March, 1925, that an attempt was made to treat the patient by ultraviolet radiation; after two months of such treatment it was obvious on roentgenographic examination that healing was taking place; by the end of the year the bones had completely healed, and after spending nearly three years in bed the child was able to walk again. From the roentgenograms taken in March, 1925, and before light treatment was actually commenced, I was convinced that the bone changes were rachitic, but looking back at old roentgenograms it is clear that there was roentgenographic evidence of rickets as early as 1922, when the knock-knee was first noticed, but the changes were unrecognized at the time.

The chemical analysis of the blood has been done in a series of cases of celiac disease complicated by rickets, both before and during treatment, and results show that usually the blood calcium is low and rises progressively under treatment, the lowest figure being 6 mg. per hundred cubic centimeters (chart 4). Estimation of the amount of calcium in the filtrate obtained by the method of ultrafiltration through collodion sacs under moderate pressure, as described by Pincus, Peterson and Kramer,[26] has also been undertaken. It is assumed by these

24. McCrudden, F. H., and Fales, H. L.: J. Exper. Med. **15**:450, 1912.

25. Parsons, L. G.: Birmingham M. Rev. **74**:33, 1913; Arch. Dis. Childhood **2**:198, 1927; Proc. Roy. Soc. Med. **22**:1043, 1929.

26. Pincus, J. B.; Peterson, H. A., and Kramer, B.: J. Biol. Chem. **68**:601, 1926.

workers that the calcium in the filtrate is ionized, and they refer to it as "free calcium," whereas the calcium that does not filter is bound to protein and practically unionized, and this they call "bound calcium." The free calcium in celiac disease complicated by rickets has been found to be low, 2.2 mg. per hundred cubic centimeters being the lowest figure obtained, 3.8 mg. per hundred cubic centimeters, according to Lathrop,[27] being the normal. The blood phosphorus is variable, but also shows a tendency to be diminished, and like calcium rises under treatment (chart 4). Vollmer and Serebrijski [28] reported a case in which the blood calcium was 5.4 and the inorganic phosphorus concentration 2.9 per hundred cubic centimeters, and Fanconi found the phosphorus low in fifteen cases.

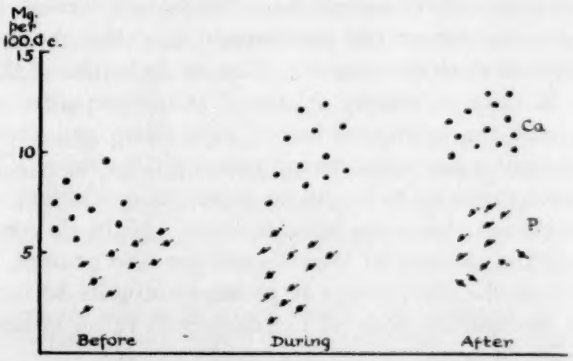

Chart 4.—Blood calcium and phosphorus in celiac disease, showing the rise in values which takes place as the result of treatment.

Clinical Characters of Celiac Disease Complicated by Rickets.—Clinically, the commonest manifestation of celiac disease complicated by rickets is genu valgum which, as in the case already detailed, may become progressively worse and worse, and finally reach such a degree of severity that walking becomes impossible. Associated with genu valgum, or at times independent of it, there is some enlargement of the epiphyses of the wrist, and a caput quadratum may also be present. Sometimes the deformities may be extreme and reach a degree such as is rarely, if ever, seen in ordinary rickets. Thus, a boy, aged 10½, had been unable to walk for two and one-half years, and when first seen was not capable of lifting himself from the prone to the sitting position. His length was 38½ inches (97.7 cm.); there was a deep Harrison's sulcus, a marked rosary with enormous enlargement of the costochondral junctions and extreme flaring of the ribs; the thorax was small and shrunken by contrast with the distended abdomen, and the clavicles

27. Lathrop, F. W.: Renal Dwarfism, Arch. Int. Med. **38**:612 (Nov.) 1926.
28. Vollmer, H., and Serebrijski, J.: Ztschr. f. Kinderh. **39**:655, 1925.

bent almost to right angles at the junctions of their inner and middle thirds. The humeri showed extreme bending; there was marked enlargement of the epiphyses at the wrist and ankle; the femora showed severe anteroposterior curvatures, and there were multiple fractures of the long bones.

Late rickets occurs in the celiac disease only if the latter is severe and of long standing, and is rarely manifest before the age of 7, the youngest patient in my series being 5 years old.

The long bones in celiac disease are fragile and atrophic, and even in the absence of rickets their roentgenographic appearances are sufficiently characteristic to enable any one who is familiar with them to suggest that celiac disease is the cause of the abnormal appearances. The trabeculae in early cases may be relatively well formed, but usually they appear to be thinner and less numerous, so that the meshwork is more sketchy and open than normal. The cortex is thinner than normal, but not so thin nor so sharply delineated as the cortex in osteogenesis imperfecta, and the epiphyseal line is quite sharp and distinct unless rickets is present. According to my radiologist colleague, C. G. Teall, the osteoporosis appears to be due to imperfect ossification rather than to any washing out of calcium from the bones. If the child has infantile rickets, then the changes of that disease are also present, and under such conditions the osteoporosis is perhaps not quite so marked as in the typical osteoporotic bone of the child with celiac disease at about the age of 3 or 4 years.

Tracing the development of rickets in celiac disease by roentgenographic manifestations, the earliest evidence occurs in an osteoporotic bone not very different from the one I have described; the lower ends of the radius and ulna are slightly enlarged, the spongy meshwork a little more open and there is slight irregularity at the epiphyseal line. In this form, as in the osteoporotic bone without rickets, fractures may occur. A fracture may indeed be the symptom that first brings the child with celiac disease under observation. Because of fractures or deformities, these children not infrequently attend surgical or orthopedic clinics, and hence the importance of widespread knowledge of the roentgenographic manifestations.

In a case of moderate severity, the appearances are very striking. There is a definite delay in the centers of ossification, and the whole bone is very atrophic, fragile, osteoporotic and translucent, with a moderately thin cortex and an open and delicate trabecular meshwork. There is a well marked rachitic metaphysis, although not so splayed out as in ordinary rickets. Not infrequently there are transverse striations in the neighborhood of the metaphysis, the cause of which will be discussed later. Single or multiple, complete and incomplete, fractures of the shaft are also frequently seen.

In the severest cases, the bones may be so lacking in calcium as to make it difficult to obtain a satisfactory roentgenogram. The osteoporosis may reach such an extreme degree that the spongy tissue is thin like a spider's web and, indeed, may seem in many areas to be nonexistent. This form may show a roentgenographic appearance of the end of the diaphysis similar to that described by Wimberger as the "passive type" of rickets, i. e., the metaphysis is not swollen, and the end of the diaphysis is relatively straight but separated from the epiphysis by an abnormally large space.

Under adequate treatment, the bones heal in a remarkable way, as is evidenced by a consideration of a series of roentgenograms, but even after complete cure of rickets the bone is for a long time more fragile and osteoporotic than normal; nevertheless, after adequate treatment both of celiac disease and celiac rickets the bones eventually appear to become normal, although transverse lines at the ends of the bones may remain for some time.

The occurrence of transverse lines in the metaphyses of long bones has been noted by many observers and in many conditions of childhood. They are, however, seen with considerable frequency in celiac disease, and there has been some controversy as to their origin. Thus Lehman wrote:

> . . . there are also to be seen a stratification consisting of multiple horizontal lines so called "year rings." These year rings seem suspicious of past rickets. They are no proof of it however since they occur in other nutritional disturbance of bone.

The real significance of these lines has been shown both by Harris [29] and by Eliot, Souther and Park.[30] They indicate periods of temporary cessation of growth and have no relationship to rickets; thus any infectious illness may leave such a scar in all the long bones, with the result that it has been suggested that a roentgenogram of the long bones of any child may throw considerable light on its medical history. Eliot, Souther and Park found:

> The formation in the bone responsible for the line . . . consists in an irregular lattice work which extends transversely across the bone and that the lattice is produced by the enlargement and cross branching of the trabeculae.

The treatment for rickets in celiac disease consists in giving ultraviolet irradiation or nonfatty preparations of vitamin D such as viosterol in solid form, or a combination of both. This cures the manifestation

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29. Harris, H. A.: The Growth of the Long Bones in Childhood, Arch. Int. Med. **38**:785 (Dec.) 1926; Lancet **1**:691, 1931.

30. Eliot, M. M.; Souther, S. P., and Park, E. A.: Bull. Johns Hopkins Hosp. **41**:364, 1927.

of rickets shown by roentgenogram and produces a normal blood chemistry. Not infrequently, a much longer time is required for the cure of the rickets of celiac disease than ordinary rickets, and either ultraviolet irradiation or viosterol in solid form must be continued as long as the celiac disease is active, otherwise relapses will occur. Some of the deformities in the severe cases are, of course, permanent, but I have been astounded by the way in which severe genu valgum will improve and almost disappear, because I had always been taught that once genu valgum had occurred, it must, for reason of mechanics, tend to increase. Ullrich [31] said that changes in the bones of a rachitic nature in celiac disease are refractory to treatment because the accompanying acidosis and hypophosphatemia are of endogenous origin. Of acidosis in celiac disease I know nothing, but the other statements of Ullrich are incorrect and based on a wrong conception of the disease, unless by "refractory" he means that treatment has to be prolonged. In all the cases at Birmingham cure was obtained by the treatment I have outlined.

We made another observation that is of some interest, namely, that after carrying out this line of treatment, the child's hair—which had previously stopped growing—resumed the normal rate of growth. This observation has been repeated in more than one case, and this symptom can, I believe, truly be regarded as belonging to the deficiency group and may be another example of the effect of vitamin A shortage on epithelial structures.

Rickets in the period of infancy probably becomes cured as a result of a partial starvation and complete or almost complete arrest of growth, and it is more than probable that the onset of late rickets is associated with a resumption of growth, although the actual cause is a deficient absorption of calcium and phosphorus from the alimentary tract. This absorption is sufficient to calcify the rarefied bones in celiac disease so long as there is no growth, but, directly any considerable growth occurs and new bone has to be formed rapidly, the defective absorption of these elements does not allow of normal calcification, and rickets results. This effect of growth in the production of rickets was demonstrated in the case of Bloch's to which reference has been made earlier, and experimental studies in rats have proved that rickets develops only during the stage of growth, for clearly if no, or very little, new bone is being formed, there is no place for rickets to develop. Harris recently showed that the growth in height occurs at three periods in the life of the child, namely, during babyhood, at the age of from 5 to 7 years and at puberty. It is in the second of what he has called "the springing-up periods of growth" that the rickets of celiac disease develops. From these con-

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31. Ullrich, quoted by Abt: Pediatrics, Practical Medicine Series, Chicago, Year Book Publishers, 1930, p. 386.

siderations it seems to me a reasonable deduction that the osteoporosis itself is actually a stage in the development of rickets; in other words, that the bone is potentially rachitic and only awaiting a period of growth actually to declare itself as such. A. F. Hess stated that lack of absorption of calcium and phosphorus from the intestinal tract brings about osteoporosis but not rickets, and he also held that the question whether osteoporosis predisposes to the development of rachitic changes is a matter of personal opinion since "clinical observations are equivocal and there are no animal experiments to guide us." He expressed the belief that it is by no means certain that there is only one variety of osteoporosis; that, for instance, the osteoporosis produced by an acid diet is identical with that due, as in celiac disease, to a deficiency of calcium. Teall's observation that on roentgenographic grounds he regards the osteoporosis of celiac disease as due to defective laying down rather than to an increased washing out of calcium is interesting in this connection, because the osteoporosis produced by an acid diet is of the latter category. I am not convinced, however, that such a distinction can be made, because the occurrence of a negative calcium balance lasting for some time has been found in celiac disease, and since the "bones are a readily available reservoir of inorganic salts" it is difficult to know whence the endogenous calcium required for a negative balance comes if not from a washing out of the bones.

From these results which I have placed before you I have come to the conclusion that rickets in celiac disease is either of the low calcium type, due to nonabsorption from the bowel, a view accepted by Alfred Hess, or of the combined low calcium, low phosphorus type. Recently Gerstenberger and his co-workers [32] produced evidence to show that rickets of the low calcium type occurs as a secondary development of a preceding rickets of the low phosphorus type owing to inadequate or interrupted specific treatment; and also that in infants receiving inadequate preventive treatment, the first change in the blood may be lowering of the calcium level, while the phosphorus remains normal. Although they definitely stated that this interpretation does not apply to the rickets of celiac disease due to low calcium or to low calcium, low phosphorus, I believe that if their observations are correct and they appear to me to be convincing, they must also apply to celiac disease.

I think it is quite possible that there has been in the rickets of celiac disease a preceding phase of rickets of the low phosphorus type, and that the rickets of the low calcium type is a secondary development, because it is obvious that there are periods in these untreated cases of celiac disease associated with rickets in which the fat absorption is better than

32. Gerstenberger, H. J.; Hartman, J. I.; Nourse, J. D., and Russell, G. R.: Acta pædiat. **30**:345, 1930.

at others, and therefore periods in which the rickets might become less active or even improve. Further, there is the curative effect of arrest of growth. Indeed, it may well be that from both these causes the genesis of the roentgenographic picture of rickets might be interrupted, and that the fully developed roentgenologic picture only occurs in celiac disease of a severe type but of rather less than maximal severity in that some growth is taking place. At any rate, I do know that if the treatment is interrupted healed rickets of celiac disease will relapse, for I have seen at least two relapses in the same child.

I may now perhaps with advantage summarize what has been said concerning the bone changes that may occur in celiac disease. The chronological order of events is as follows: first, in infancy there is an osteoporotic bone with rickets; second, as the celiac disorder becomes more pronounced and growth is more or less completely arrested, a stage occurs in which there is a fragile osteoporotic bone but no rickets, and if the celiac disease has been present for two or three years often there are transverse lines in the metaphysis which indicate periods of complete arrest of growth; third, at the age of from 5 to 7 years when growth is more rapid, the bone is still osteoporotic and fragile, but rickets recurs.

It is only rarely that all these stages are seen in the same child; usually, the second and third only are seen; moreover, the occurrence of the third stage in any case indicates that the treatment has been inadequate.

The underlying cause of these bone changes is a deficient absorption of calcium and phosphorus from the intestine, the result of an impaired absorption of fat and vitamin D. Such a deficiency of fat-soluble vitamin D is obviously not improved by giving a "fat-free" diet, especially as the effect of such a diet is to promote growth, because this factor—growth—is the activating cause of the late rickets in celiac disease.

The realization of the possibility of the development of rickets during the rigid dieting that forms so essential a part of the treatment in celiac disease is of the greatest importance, because appropriate preventive measures can then be instituted.

If one accepts, as I believe one must, the experimental and clinical observations of Mellanby,[33] that an adequate supply of vitamin D is necessary for the proper formation of the teeth and the prevention of dental caries, the abnormal condition of the teeth in celiac disease must also be regarded as a deficiency symptom; thus, the enamel is often poorly formed, there is a marked tendency to dental caries, and dentition, both temporary and permanent, is frequently delayed. I have already

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33. Mellanby, May: Tr. Edinburgh M. Soc., 1928-1929, p. 24, in Edinburgh M. J., March, 1929.

referred to a girl, aged 17 years, who showed such an extreme degree of delayed dentition that none of her permanent teeth were erupted.

Finally, to conclude the catalogue of deficiency symptoms that may be found in celiac disease, a case recorded by Hunter [34] suggested that changes may occur in the ocular lens. The case was that of a woman, aged 34 years, who was the subject of idiopathic steatorrhea associated with tetany and dwarfism and in whom slit-lamp examination of the ocular lenses showed a collection of opacities in each lens similar to those recorded in postoperative tetany. This patient had suffered from intestinal symptoms, recurrent tetany and genu valgum since childhood, and the case appears to me to be an instance of celiac disease persisting into adult life. Since reading of this case, I have had slit-lamp examinations carried out in several children with celiac disease, but so far lenticular opacities have not been detected, but it may well be that a low calcium concentration of the blood extending over some years is required for their production.

OTHER GENERAL SYMPTOMS

Pyrexia.—In my experience, pyrexia has not been an important or arresting symptom, although sometimes a small degree of nocturnal fever which may be accompanied by night sweats occurs for weeks or even months. A higher degree of fever may occur with parenteral or enteral infections or be associated with a diarrheal period of the disease. Some of these children react to fat in a manner that suggests an allergy, and the smallest amount of extra fat may produce pyrexia and intestinal symptoms.

Anemia.—Some degree of anemia, according to Gee, is usually present. The anemia is of the hypoplastic type with few or no nucleated red cells, a low reticulocyte count and a low color index. The white cell picture is usually unaltered, but there may be a leukopenia and sometimes an increase in eosinophils and mononuclears. This anemia is probably nutritional in origin, and is of interest because we have never been able to find any evidence of a megaloblastic response such as may occur in sprue; indeed, a true megaloblastic anemia in childhood is a rarity. In a few cases, however, "anemia of the pernicious type" has been recorded. Strandquist,[35] who has recently reviewed this subject, expressed the opinion that the anemia is related to the intestinal condition, being in fact due to a hypovitaminosis resulting from defective intestinal absorption, and that the very grave anemia that sometimes occurs is the result of very severe intestinal symptoms. He also said that in some cases the anemia is combined with the "hemorrhagic dia-

34. Hunter, Donald: Lancet **1**:999, 1930.
35. Strandquist, B.: Rev. franç. de pédiat. **5**:728, 1929.

thesis," and that the latter is due either to scurvy or, very rarely, to certain biochemical alterations in blood plasma, and that in these two groups of cases the prognosis is bad. This latter group has been separated off by Fanconi and called "hypothrombinemia" and is due, according to him, to alteration of the ferments concerned in coagulation, meaning, I presume, thrombokinase. In a recent paper by Dalldorf,[36] it was shown that in experimental scurvy the hemorrhagic diathesis develops earlier than any other known sign of the disease, and that it persists in some degree throughout the illness; herein, it seems to me, lies the probable explanation of all the cases that show this diathesis.

Strandquist expressed the belief that the rapid increase of anemia which sometimes occurs is generally due to an infection and is but an example of that instability and overresponse to any abnormal influence which is so characteristic a feature of celiac disease.

Some writers describe an increase in the size of the spleen, and Gee stated that it is sometimes enlarged. Personally, I can recall only two cases with a definite splenomegaly, but the condition is not unlikely to occur in cases that show a protracted fever, since any form of continued fever in childhood may cause splenomegaly, or it may be an expression of the lymphatic hyperplasia not uncommonly seen in nutritional anemias. In this connection, Taylor [37] described an extraordinary case.

> A girl, the subject of celiac disease, was noted when 5 years of age to have a severe secondary anemia and a moderately enlarged spleen. When 6 years old a leukopenia was found, and from then the leukocytes progressively diminished and the spleen enlarged. At 9 years of age a profuse bowel hemorrhage occurred; a diagnosis of Banti's disease was made, and the spleen removed. The spleen "showed hypertrophy of the connective tissue similar to that found in Banti's disease," but the most striking change was that after the operation the stools appeared like normal stools, they were darker, firmer and contained much less fat than before, although the diet was precisely the same.

Taylor uses this case as evidence in favor of the view that there is some pathologic change in the liver in celiac disease, but the evidence is open to criticism. On reading the case report, it is clear that the child had responded to treatment, but that with the hemorrhage there was a "return of the indigestion," and the estimation of the fat in the stool showed that 4.7 Gm. of fat were excreted daily. After operation, her symptoms improved and she clearly passed into a nondiarrheal phase, but her stools still showed 2.38 Gm. of fat per day, a figure strictly comparable with those we have obtained in nondiarrheal cases on several occasions. In other words, the improvement in the stool is

36. Dalldorf, G.: J. Exper. Med. **53**:289, 1931.
37. Taylor, Todd: Celiac Disease, Am. J. Dis. Child. **25**:46 (Jan.) 1923.

not different from what would be expected in a nondiarrheal phase of an ordinary case of celiac disease, and therefore it appears to me correct to regard this child as suffering from two conditions, celiac disease and the syndrome of Banti.

The tongue not infrequently presents an appearance something like sprue, being smooth, red and somewhat free from papillae, a rather characteristic appearance which is more marked in the diarrheal than in nondiarrheal periods.

COURSE AND PROGNOSIS

Celiac disease runs a long drawn out course marked by many ups and downs. In spite of careful treatment, progress toward recovery is slow and intermittent, and diarrhea occurs from time to time, possibly from irregularities and premature changes in the diet or from parenteral infection. I cannot, therefore, accept Miller's statement that the patient should improve smoothly, if slowly, because even with the most stringent and correct dieting it is impossible to prevent the occurrence of parenteral infections; nevertheless, a cure can usually be promised if treatment is carried out efficiently. The length of time that is required to effect a cure varies in different persons, even though the manifestations of the disease may appear to be of similar severity when treatment is started. Without any treatment it is possible for the child to survive as a stunted, feeble person, since improvement usually occurs at puberty; not infrequently, however, the child succumbs before that period from some intercurrent infection, although death from uncomplicated celiac disease is relatively rare.

The views of some other writers on the prognosis in celiac disease differ from my own. I have already given a quotation from Gee on this point to the effect that "Death is a common end," and he added, "is mostly brought about by some intercurrent disorder." It is not clear whether he is referring to untreated or treated cases, but I am inclined to think that it is the former. Gibbons also thought that the majority of the sufferers died from the disease; Lehndorff and Mautner are of opinion that the prognosis of the severe type of the disease is not good, and Knopfelmacher spoke of a 50 per cent mortality. On the other hand, Still had a mortality of 14 per cent in forty-one cases; Schaap [38] collected one hundred and fourteen cases with an 11 per cent mortality, and Howland and Sauer [39] had even better results, the former treating thirty and the latter twenty-five patients without a death. It is difficult

38. Schaap, L.: Arch. d. mal. de l'app. digestif **16**:914, 1926.

39. Sauer, L. W.: Celiac Disease: Simple Three-Phased High Protein Diet, Am. J. Dis. Child. **29**:155 (Feb.) 1925; Celiac Disease (Chronic Intestinal Indigestion): Etiology, Prognosis and Standardization of Treatment, ibid. **34**:934 (Dec.) 1927.

to give correct mortality statistics of celiac disease because death is so frequently due to intercurrent disease, but unless the services of a skilled statistician are available, the clinician can, I believe, count as fatal cases of celiac disease only instances in which death occurs during the course of the disease, however disconcerting such a course may prove to his *amour propre*. The only exception to such a rule that might be permitted is if death were the direct result of an accident. Applying this rule to the foregoing result would slightly modify the figures of Sauer, who excluded one patient who died directly after admission to hospital. Of our patients, ten are known to have died, giving a mortality rate of 10.6 per cent; this includes at least two patients who were moribund when they came under observation and died in a few days, and one child in whom death was probably due to measles.

In many cases in which recovery appears to have taken place, the stools show more fat than normal; indeed it is probable that "clinical" precedes "biochemical" recovery, but by what period is unknown—probably the period varies with different cases. Complete "biochemical" and "clinical" recovery have, however, been observed in some of our cases, and in some instances after puberty has been established "biochemical" and "clinical" recovery have occurred rapidly. The disease rarely persists into adult life, but Hunter's case, to which I have referred, certainly seems an instance in which this has occurred. My colleague, A. P. Thomson, has under his care two similar cases; Gairdner-Hill [40] reported a case which showed symptoms of celiac disease and rickets still persisting at the age of 22. Spence informed me that he has two patients under his charge who still show the clinical characters of the disease in adult life, and I have one patient who has now reached adult life whose treatment has been intermittent and who is still uncured.

Increase in weight and height are good tests of improvement, and it is stated that, generally speaking, children with celiac disease reach an average height in adult life, but in my experience any marked retardation of growth leaves its mark and, although after recovery growth may be considerable, the child never reaches normal height. The first case I recognized was in 1912; the patient was then 3 years old and had an extremely severe case. She had scurvy and several attacks of tetany, and has been completely cured for at least twelve years, but her growth has been considerably affected and now, at the age of 22, her height is 4 feet 11 inches (150 cm.).

As the child improves, fat is deposited in the subcutaneous tissues, and in some children for a few years after cure is complete the distribution of fat is very similar to that seen in mild examples of Fröhlich's

40. Gairdner-Hill, H.: Proc. Roy. Soc. Med. **22**:1033, 1929.

syndrome, and the weight for height proportion is greater than in the normal child. This is probably another manifestation of that abnormal fat metabolism which is so striking a feature of the celiac disorder.

In arriving at the present day conception of the clinical characters and course of celiac disease, four important landmarks stand out and, very appropriately, the credit for these can be divided almost equally between American and British workers. These are:

1. The stress laid by Gee on the intestinal symptoms.
2. The insistence by Herter on infantilism as an outstanding symptom.
3. The emphasis by Howland on the necessity of giving for long periods a diet almost exclusively protein in character and the conspicuous success achieved by the method.
4. The demonstration, largely by British workers, that many of the symptoms of the disease, such for instance as scurvy, tetany, rickets and maldentition, are signs of a deficiency disorder.

MORBID ANATOMY

There is no known morbid anatomy of celiac disease; postmortem examinations are somewhat rare, and the abnormal appearances that have been found in the course of such examinations are due either to secondary infections or the results of malnutrition. The presence of pale stools and steatorrhea has led to the supposition that the liver or the pancreas would show pathologic changes. This has not been borne out in actual fact, although it is true that in some cases the liver has been made out clinically and pathologically to be smaller than normal, and in two or three cases some excess of fibrous tissue or small-celled infiltration around the ducts of the pancreas has been found. Malnutrition is the probable explanation of such changes in the liver and pancreas, and the fact that the fats are well split rules out any dysfunction of the pancreas. Schick and Wagner [41] found in one case some changes in the pancreas, thyroid, suprarenals and thymus, but other well attested postmortem examinations recorded by Miller and others have shown the absence of any chronic changes in the intestine, pancreas, liver or ductless glands which would account for the protracted symptoms. After all, symptoms that are so severe and protracted as those occurring in well marked celiac disease should, if the disease be due to an anatomic change, show very definite lesions. The finding after much scratching about of some small grains of reward in the shape of an alteration in a few cells does not seem sufficient to justify an exulting cackle but rather should stimulate research in other directions. Certainly one can agree with Gee that "naked eye examination of dead bodies throws no light upon the nature of the coeliac affection."

41. Schick, B., and Wagner, R.: Ztschr. f. Kinderh. **35**:263, 1923.

In an examination of two fatal cases of celiac disease, Bloch made an attempt to eliminate any postmortem changes by injecting the peritoneal cavity and stomach of each child with a 10 per cent solution of formaldehyde shortly after death. There was no ulceration, the mucous membrane of the alimentary canal being intact, but microscopic examination showed a subchronic inflammation of the stomach and intestine. The glands in the stomach and intestine were normal except that the parietal cells in the gastric glands were without secretory capillaries, and granules were present only in a few secretory cells. Bloch said that this inactive condition might be taken as a sign of digestive insufficiency, but the changes were so slight that they could not be regarded as irreparable. The pancreas, the liver, the parathyroids and other endocrine glands were normal. These results were communicated to the Fourth Scandinavian Paediatric Congress, and although Bloch thought that they suggested "a chronic insufficiency of the digestive glands together with a superficial subchronic inflammation of the mucous linings," I gather that he did not lay great stress on this finding, because in the subsequent discussion Fröhlich said: "Bloch in his conscientious investigations has not been able to find any changes in the digestive system." In April, 1931, one of the children in our series died, probably from measles. The abdominal viscera were preserved in the manner described by Bloch, and on microscopic examination showed no sign of disease.

Before leaving the question of morbid anatomy, mention must be made of the suggestion made by Ryle [42] that celiac disease "can best be accounted for by an obstructive lesion (probably infective in origin, as the disease is acquired and not congenital) of some part or parts of the lacteal tree." Ryle drew attention to the resemblance in the clinical symptoms and stool analyses of patients suffering from sprue, celiac disease and tabes mesenterica with obstruction of the lacteals, and described two cases of the latter in which, during the course of a laparotomy, the lacteals were seen to be enormously overdistended with chyle, a condition that has also been seen by Jones [43] during operations for appendicitis in two cases of tropical sprue. One certainly knows that steatorrhea may occur as a result of obstruction of the lacteals by enlarged tuberculous glands, but such glands are not usually present at autopsy in cases of celiac disease, although in one of my cases there was a moderate degree of enlargement of the glands, which on microscopic examination showed tuberculous foci. Ryle maintained that the failure to discover overdistended lacteals at necropsy is of no significance, because the overdistention only happens during life and on a more

42. Ryle, J. A.: Guy's Hosp. Rep. **74**:1, 1924.
43. Jones, Davenport: Lancet **2**:525, 1925.

or less normal diet. Neale and I [44] have, however, reported a fatal case of celiac disease in which it was possible by Gerota's method to inject from the submucous coat of the intestines the lacteals, lymphatic vessels and lymph glands of the mesentery, a result that showed clearly that at any rate in this particular case there was no lymphatic obstruction.

I have now under observation a case which shows some points of interest in this discussion.

A girl, aged 6 years, three years ago developed celiac disease; up to that time she had never taken any but "certified" milk. The skimmed milk used in dieting for celiac disease was, however, not obtained from certified milk. She appeared to make a complete recovery, and after a year on skimmed milk gradually resumed feeding on "certified" milk and eventually a normal diet. A few weeks ago she began to suffer with paroxysms of pain in the lower portion of the abdomen. These were thought to be appendicular in origin, and an operation was decided on. Before this was done, the stools became again pale and bulky, and the dried feces showed a fat content of 40 per cent. At the laparotomy the appendix was not particularly unhealthy but moderately enlarged, and caseating tuberculous glands were found in the ileocecal angle, and there were recent tubercles on the serous coat of one part of the ileum. The lacteals were nevertheless all of normal size. The appendix only was removed at the operation. When the child returned to a normal dietary after the operation, there was no abdominal pain and chemical examination of the stools revealed a normal fat content.

METABOLISM IN CELIAC DISEASE

The characteristic features of celiac disease are the presence of steatorrhea and the resultant absence of stored fat in the fat depots. When the reason for celiac steatorrhea has been discovered, the cause of celiac disease will be obvious. Before entering into a discussion of the causation of this disorder, there are certain other facts that have been discovered by laboratory and clinical observation that should be detailed.

Fats.—It has already been pointed out that although the stools in celiac disease are often large and contain a high percentage of fat, thereby showing an impaired absorption of fat, yet there is no defect in fat-splitting, because the proportion of split to unsplit fat in the stool is normal. Now, in spite of the presence of this large proportion of fat in the stools, the absorption of fat is often—particularly in the nondiarrheal periods—surprisingly high. For instance, a child on a normal diet whose dried feces contained 42.1 per cent of fat absorbed 83.5 per cent of its total fat intake. The significance of these figures may perhaps be better appreciated if it is remembered that the normal child taking a mixed diet absorbs from 94 to 98 per cent, and that children suffering from conditions that exclude the bile from the intestine, such as biliary atresia, only absorb an average of 30 per cent of their fat intake (chart 5).

44. Parsons, L. G., and Neale, A. V.: Arch. Dis. Childhood **3**:176, 1928.

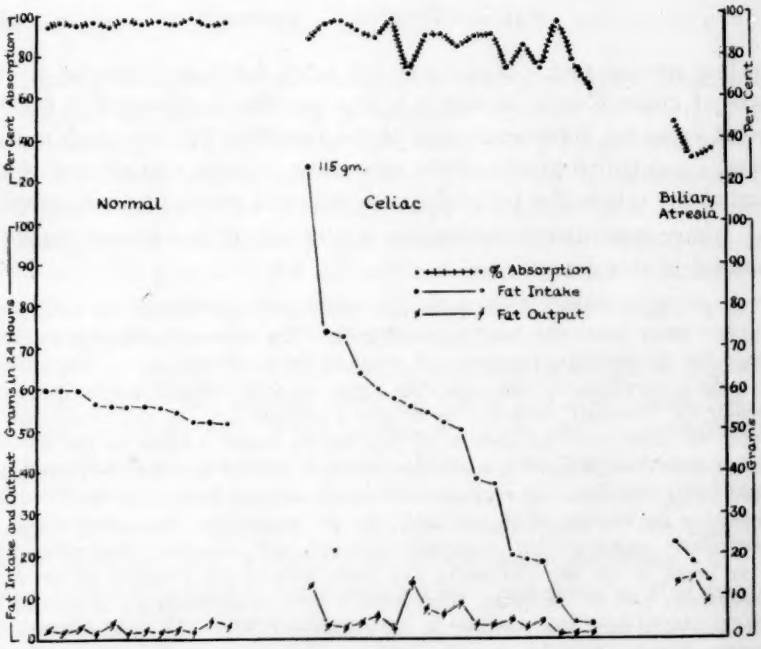

Chart 5.—Fat intake and output per twenty-four hours in grams and percentage of absorption in a series of normal children, children suffering from celiac disease and children suffering from biliary atresia.

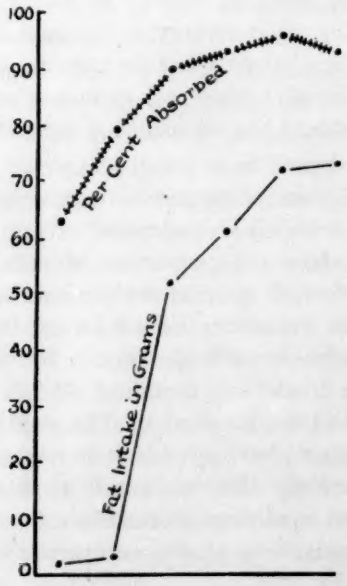

Chart 6.—The increase in fat absorption in celiac disease, accompanying an increased fat intake.

Further, within certain limits, as in normal children, an increase in the fat intake produces an increased fat absorption, as though the greater "head" of fat in the bowel forced more fat through the absorbing area of the intestine. This result, which occurs both in the same person and also when one patient is compared with another, is probably one of the reasons why occasionally children suffering from this disorder have done well on cod liver oil. Notwithstanding these results, a high, or even a normal, fat intake cannot as a rule be maintained for any length of time, because it produces an increase in the number, size and offensiveness of the stools (chart 6).

The amount of fat absorbed may also depend on the type of fat used in the food. These observations are based on the results obtained by giving to children with celiac disease, in their nondiarrheic periods, a basal diet that is practically fat-free and adding to this 60 Gm. of lard, linseed oil or butter; in other cases, breast milk was given, and in others again cow's milk, with the addition of a synthetic infant food.

The question as to whether fecal fat can be regarded as unabsorbed food fat and whether therefore it is right to assume that faulty absorption of fat is the cause of the fatty stools of celiac disease has been raised by Bauer [45] and others. Hill and Bloor,[46] working with dogs and cats, came to the conclusion that the amount of fat in the food affects the amount of fecal fat only to a comparatively small extent, and that the properties and composition of fecal fat are independent of, and different from, the fat in the food. Sperry and Bloor [47] said that almost as much fat appears in the feces after a fat-free diet as after a fat diet; they think it probable, considering the marked similarity between the lipoid composition of the blood and feces, that the fat of the feces has its origin largely in the blood. In the experiments on the absorption and retention of vitamin A carried out by Rowntree,[12] which have already been quoted, it was found that two of the children excreted more vitamin A than they took in, and this was regarded as being due to the excretion of fat from the blood into the intestine. The possibility that a small amount of fat is excreted from the blood cannot be denied, for in one case of celiac disease observed over a period of six days the daily output of fat was 1.2 Gm., whereas the daily intake was 1 Gm. Nevertheless, in balance experiments on more than a hundred atrophic children, as well as in those carried out on children suffering from celiac disease, we have been unable to find any evidence that almost as much fat appears in the feces after a fat-free diet as after one containing the normal amount of fat. In fact, in infantile atrophy we have been able to reduce the output of fat in the feces to 0.2 Gm. daily

45. Bauer, E. L.: Celiac Disease, Am. J. Dis. Child. **35**:414 (March) 1928.

46. Hill, E., and Bloor, W. R.: J. Biol. Chem. **53**:171, 1922.

47. Sperry, William; and Bloor, W. R.: J. Biol. Chem. **60**:261, 1924.

when the fat intake was reduced to 1.5 Gm. It should also be borne in mind that, even if it is conceded that there is a small amount of fat in the stool which is not derived from the food, there are other possible sources of origin than the blood; for instance, desquamated intestinal cells, bacteria and the digestive secretions.

If the fat in the feces in celiac disease is largely excreted from the blood and not unabsorbed food fat, then two things should follow: first, the composition of the fat in the feces should be fairly constant, and not vary with the composition of the fat in the food; second, the fat in the blood should be higher in the child with celiac disease than in the normal child.

The proof that fecal fat is or is not unabsorbed fat is extremely difficult, but Hill and Bloor, as well as Holmes and Kerr,[48] showed that the fecal lipoids differed from the fat ingested in both iodine and saponification number, and hence we thought that an attempt might be

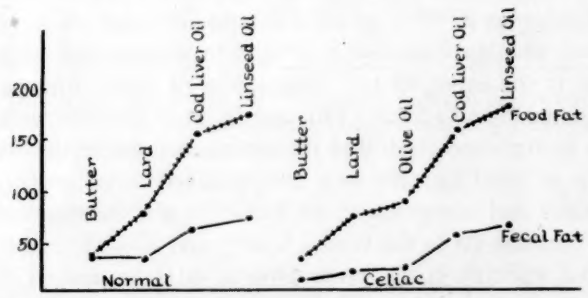

Chart 7.—Iodine values of food fat and fecal fat in normal children and those with celiac disease fed on various fats.

made to determine the answer to this problem in celiac disease. We therefore incorporated various fats in the basal diet in the way previously described, and the ether extract of the resulting feces was treated with hydrochloric acid to liberate fatty acids and again extracted. The iodine value of the final residue containing the free fatty acids and unsaponifiable material was determined by Wijs' method. It was repeatedly noticed that when the children were having cod liver oil or linseed oil the extracted fecal fat was much softer than when they were having butter or lard, indicating even by casual observation that the melting point, and therefore presumably the composition, of the fecal fat was affected by the food fat. The iodine values of the fecal fats, taken as a whole, although not identical with the food fats, show similar variations, rising and falling together as will be seen by reference to the graphs. These results therefore appear to warrant the conclusion that the fecal fat is dependent to some extent on the food fat (chart 7).

48. Holmes, A. D., and Kerr, R. H.: J. Biol. Chem. **58**:377, 1923

Blood Fat.—Moncrieff and Payne [49] reported the finding of a high blood fat in celiac disease in six instances, and Bauer obtained a similar result in one case. There are, however, many fallacies about blood fat estimations that have to be considered before any definite statements can be either accepted or made. For instance, Patterson [50] showed that it is extremely difficult to obtain a constant value for blood fat because in the fasting person any exercise mobilizes fat and thus raises the blood fat value; but if the estimation is carried out while resting after

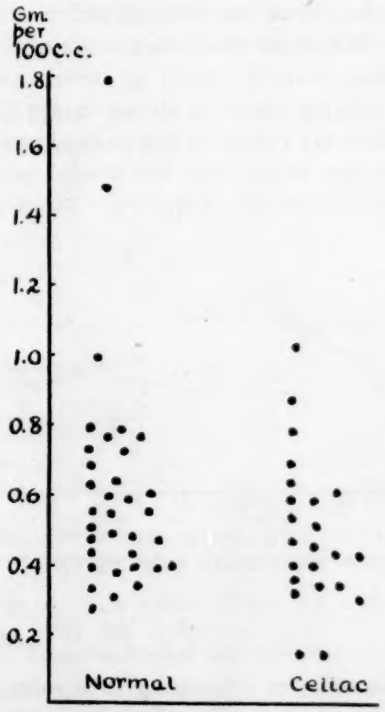

Chart 8.—Fasting blood fat values expressed as grams per hundred cubic centimeters in normal children and in those with celiac disease.

a night's fast, the results are constant for the same person. As the result of examining thirty-four normal children and twenty-three patients with celiac disease under such conditions, it is obvious that there is considerable variation in the results obtained in different persons, but the range is less and on a lower level in the children with celiac disease than in the normal children. The average value for celiac disease is 0.474 Gm. per hundred cubic centimeters as compared with 0.617 Gm. per hundred cubic centimeters for normal children; that is, these obser-

49. Moncrieff, A., and Payne, W. W.: Arch. Dis. Childhood **3**:16, 1928.
50. Patterson, J. W. T.: Biochem. J. **21**:958, 1927.

vations indicate that blood fat in celiac disease has a lower and not a higher value than normal (chart 8). Again, as the result of observations carried out on human beings, McClure and Huntsinger [51] pointed out that the increase in the fatty acid concentration of the blood which occurs after the ingestion of oleic acid is not solely due to an increase in oleic acid but that it is in part due to mobilization of fat either from the liver or adipose tissues, and further that such mobilization occurs after a meal of any variety of food (fat, protein or carbohydrate). A series of blood fat estimations were therefore carried out in normal children and in those suffering from celiac disease after the administration of an emulsion containing 60 Gm. of olive oil. In the normal children there is usually an initial rise of fatty acid due to the mobilization of fat which is absent in the children with celiac disease; there is, however, a delayed rise in the latter which may be the result of absorption, but in any case the whole curve is set at a lower level (hypolipemia). Another comparative series of blood fat esti-

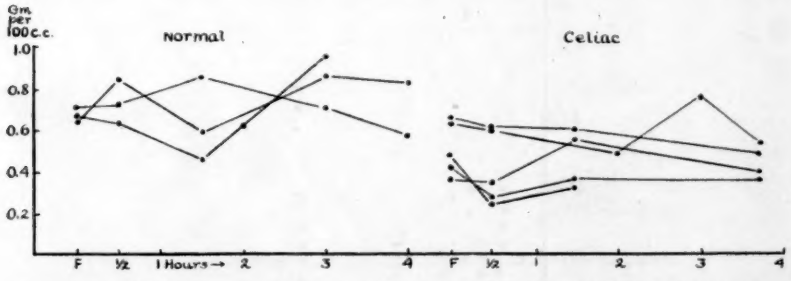

Chart 9.—Blood fat curves (grams per hundred cubic centimeters) in normal children and in those with celiac disease following the administration of 60 Gm. of olive oil.

mations were carried out after the ingestion of 15 Gm. of dextrose in 4 ounces of water; here again the initial rise in value of blood fat found in the normal child is not present in celiac disease, and this curve is also on a lower level (chart 10).

On first principles, it might be argued that the presence of a low concentration of fat in the blood should not be regarded as evidence against, but rather as evidence in favor of, an increased secretion from the blood. On the basis of the analogy to diabetes, it would, however, appear probable that just as there is in that disease a hyperglycemia, in celiac disease there should be a hyperlipemia if the assumption that the fat is excreted from the blood is correct. There is, however, a direct rather than an analogous proof of the true significance of the hypolipemia, because when the blood fat curves are examined it is noticeable that in celiac disease there is not the initial rise that usually occurs in

51. McClure, C. W., and Huntsinger, M. E.: J. Biol. Chem. **76**:1, 1928.

normal children and that is produced by the mobilization of fat from the fat depots; in other words, there is no source of storage supply to provide for the increased fat secretion.

We have, therefore, been unable to find any evidence to support the view that the increase in the fecal fat in celiac disease is due to increased excretion of blood fat, and the most probable explanation of the hypolipemic curve is that it is due to defective absorption from the intestine. It would therefore appear that as the child improves and fat is laid down, the hypolipemic curve should become less marked; I have not, however, any evidence to bring forward in support of this, although I believe that herein lies the reason why some of the curves are higher than others.

Carbohydrates.—Many writers on celiac disease hold the view that not only is the metabolism of fat faulty, but also that there is an

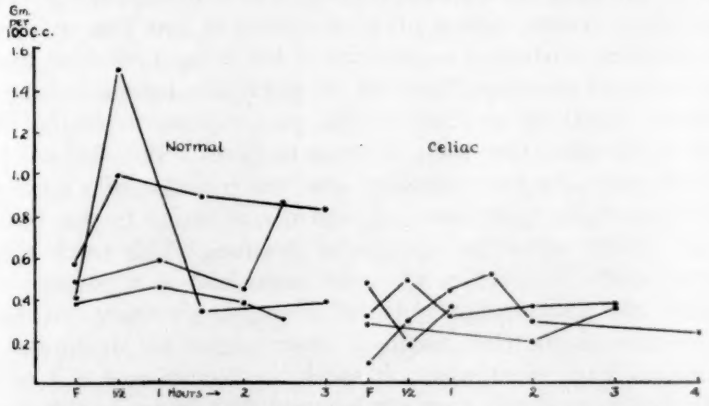

Chart 10.—Blood fat curves in normal children and in those with celiac disease after the administration of 15 Gm. of dextrose.

abnormal metabolism and intolerance to carbohydrate, particularly starch. Miller regarded carbohydrate indigestion as a secondary symptom, and in 1921, Howland drew particular attention to the great importance in treatment of recognizing this intolerance. It has already been pointed out that the frothy, yeasty appearance of the stool is probably due to fermentation of carbohydrates. According to Morse, "it is generally agreed that the chief abnormality in this type is the fermentation of carbohydrates and that the malabsorption of fat is relatively unimportant." From what I have already said on the metabolism of fat, it is clear that I cannot agree with that view, but I am sure that carbohydrate intolerance is very marked in the severe cases, although it is probable that in slighter cases this intolerance is relatively less marked than the fat defect. I also agree with Marfan [52] that particularly in

52. Marfan, A. B.: Nourrisson **17**:321, 1929.

cases in which the fats but not the carbohydrates have been restricted in the diet the stools may take on the characters of a fermentative diarrhea; that is, they are evacuated explosively, are of a frothy constituency, very acid in reaction and contain mucus.

As carbohydrate balance experiments are practically impossible, an attempt has been made to estimate the degree of absorption by estimating the blood sugar values. Examination of blood sugar curves after a meal of dextrose shows that the curve is hypoglycemic in type (chart 11), an observation that has been made by several workers; thus MacLean and Sullivan [53] found that there was very little alteration in the blood sugar curve following the ingestion of dextrose, and Thaysen and Norgaard [54] showed that although there was a rise in the curve after the ingestion of dextrose, it was subnormal. Svensgaard [55] also obtained similar results, and a comparison with the curves that have been obtained in some of my cases with those obtained from normal children demonstrates the difference clearly. It is interesting to note that an injection of epinephrine produces a normal rise of blood sugar, showing that the mobilization of sugar and therefore the glucogenic function of the liver is normal. MacLean and Sullivan also made another interesting observation to the effect that while dextrose produces a very flat and hypoglycemic curve, the curve obtained after the ingestion of a mixture of equal proportions of levulose and dextrose is similar to that found in normal children after the ingestion of dextrose. This result suggests a more normal metabolism of invert sugar and is a possible explanation of the acknowledged value of banana in treatment, because the carbohydrate in the ripe banana is invert sugar, but in drawing any conclusions from these results it should be remembered that levulose is absorbed more slowly from the intestine than dextrose; that the rate of absorption of any hexose is modified by the simultaneous addition of another sugar, and that levulose injected into the mesenteric vein is utilized only one-fifth as quickly as dextrose. These workers, having definitely ruled out the possibility of a lowered renal threshold, think that the reason for the hypoglycemic curve obtained after the ingestion of dextrose may be connected with an endocrine defect and believe that some of the evidence they have obtained is against it being due to a defect of absorption.

Thaysen [56] showed that in a child, aged 11 years, during a "bad period" of celiac disease the respiratory quotient determined after

53. MacLean, A. B., and Sullivan, R. C.: Carbohydrate Tolerance in Infants and in Young Children with Celiac Disease, Am. J. Dis. Child. **38**:16 (July) 1929.

54. Thaysen, T. E. H., and Norgaard, A.: The Regulation of Blood Sugar in Idiopathic Steatorrhea, Sprue and Gee-Herter's Disease, Arch. Int. Med. **44**:17 (July) 1929.

55. Svensgaard, E.: Acta pædiat. **9**:22, 1930.

56. Thaysen, T. E. H.: Blood Sugar Regulation in Idiopathic Steatorrhea, Arch. Int. Med. **44**:477 (Oct.) 1929.

twelve hours' fasting rose nearly to 1 (actually to 0.94), after the ingestion of 70 Gm. of dextrose in about 700 cc. of water. This is the same figure as in normal people and was therefore regarded by him as proof that the dextrose had been absorbed. He believed that the low blood sugar curve could not be the result of increased oxidation of carbohydrates consequent on the loss of fats, because the respiratory quotient on an ordinary diet (0.88) showed that there was a fair reserve supply of carbohydrates in the form of glycogen, and concluded that the low sugar curve could scarcely be due to undernutrition but was more probably the result of some toxic effect on the endocrine glands which regulate the blood sugar content. It is doubtful whether such definite

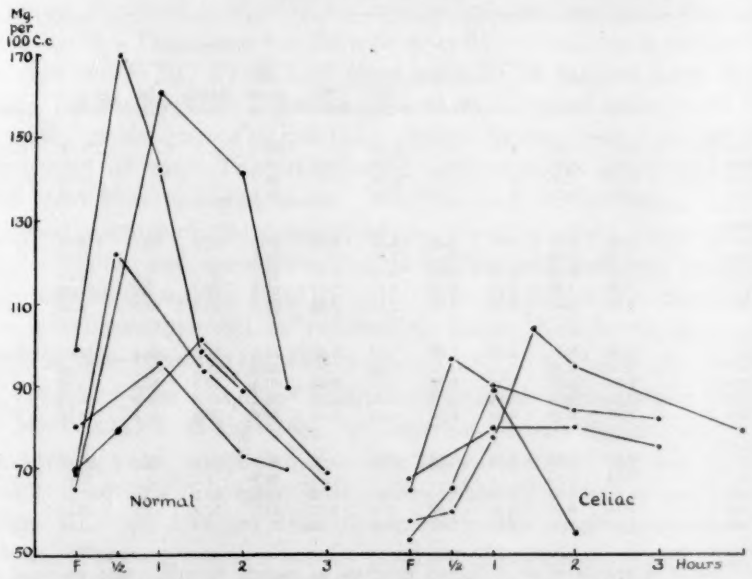

Chart 11.—Blood sugar curves in normal children and in those with celiac disease after the injection of 15 Gm. of dextrose.

conclusions as these can be drawn from the respiratory quotient, because Cathcart and Markowitz [57] showed that the values obtained are really the resultant of all the metabolic processes and do not necessarily indicate the metabolism of any particular food material. It might be argued that a case recorded by Poynton and Cole [58] in which celiac disease was associated with glycosuria and a high blood sugar was evidence of an endocrine disturbance in celiac disease, but it is more likely that this particular case together with three other similar cases described in the literature are instances of diabetes occurring in celiac children; further,

57. Cathcart, E. P., and Markowitz, J.: J. Physiol. **63**:309, 1927.
58. Poynton, F. J., and Cole, L. B.: Brit. J. Child. Dis. **22**:30, 1925.

the similarity of the blood sugar and blood fat findings suggests that faulty or delayed absorption is the real cause of the hypoglycemic curve, a view borne out by the fact that exactly similar curves have been found in sprue and in tuberculosis of the mesenteric glands associated with large fatty stools. It is also of some interest to note that Jensen [59] found that a low blood sugar curve after ingestion of dextrose is not a rare occurrence in normal children, although the curves in steatorrhea are more protracted and steady than those in normal children.

TABLE 1.—*Nitrogen, Calcium, Phosphorus and Chloride Balances in Cases of Celiac Disease During Nondiarrheal Periods and on Diets Varying in Fat Content* *

		Output					Percentage			Fat	
	Intake	Fecal	Urinary	Total	Absorbed	Retained	Absorption	Retention	In Urine	Intake	Output
Nitrogen											
Case O.....	14.22	1.03	....	....	13.20	....	92.7	....	....	116.00	13.40
Case C.....	3.86	0.60	....	....	3.26	....	84.5	....	....	36.25	3.86
Case O.....	19.19	2.26	....	....	16.93	....	88.2	....	....	19.10	3.05
Case B.....	7.97	0.33	....	....	7.64	....	95.8	....	....	4.20	0.85
Calcium											
Case O.....	3.37	3.27	0.34	2.61	1.10	0.76	32.6	22.6	12.8	116.00	13.40
Case P.....	2.28	1.03	....	....	1.25	....	54.7	....	....	50.80	8.40
Cace C.....	1.30	0.68	0.06	0.73	0.63	0.57	48.1	43.9	7.5	36.25	3.86
Case O.....	4.32	1.65	0.13	0.78	2.67	2.54	61.8	58.7	7.2	19.10	3.05
Case B.....	4.05	0.67	0.11	0.78	3.38	3.28	83.4	80.8	13.6	4.20	0.85
Phosphorus											
Case O.....	2.15	0.51	0.49	1.00	1.64	1.15	84.1	53.5	49.4	116.00	13.40
Case P.....	1.26	0.30	....	....	1.08	....	78.4	....	....	50.80	8.40
Case C.....	0.64	0.37	0.15	0.52	0.27	0.12	73.1	19.1	29.1	36.25	3.86
Case O.....	2.38	0.38	0.56	0.94	2.01	1.45	84.1	60.8	59.0	19.10	3.05
Case B.....	0.92	0.24	0.33	0.58	0.65	0.33	42.6	36.5	57.6	4.20	0.85
Chloride											
Case O.....	7.10	0.25	2.82	3.07	6.86	4.03	96.5	56.8	62.0	116.00	13.40
Case P.....	3.64	0.44	....	....	3.20	....	88.0	....	....	50.80	8.40
Case C.....	1.35	0.08	0.51	0.60	1.27	0.76	93.9	53.8	....	36.25	3.86
Case O.....	7.26	0.61	3.92	4.53	6.65	2.75	71.6	37.6	....	19.10	3.05
Case B.....	1.67	0.56	1.31	1.87	1.11	(—0.20)	61.6	0.0	....	4.20	0.85

* Calcium is calculated as CaO and chlorides as sodium chloride. The amounts are expressed in grams per twenty-four hours.

The hypoglycemic curve therefore forms an interesting parallel to the hypolipemic one, but whereas by the injection of epinephrine normal mobilization of sugar can occur, fat cannot be mobilized at all because there is not sufficient depot fat to meet the summons. In passing, it may be noted that in diabetes the opposite state of conditions is said to exist; namely, that a hyperlipemic curve occurs having similar characteristics to the hyperglycemic curve, that is, a quick rise to a higher level than normal and a delayed return to the fasting level. This correlation between lipemic and glycemic curves has also been shown by Rony and Levy [60] to exist in obesity.

59. Jensen, I.: Acta pædiat. **9**:405, 1930.
60. Rony, H. R., and Levy, A. J.: J. Lab. & Clin. Med. **15**:221, 1929.

Since these lectures were written I have read an extremely interesting review on celiac disease by Morse and, containing as it does some delightfully caustic remarks, I have taken the opportunity to introduce one or two of them into my text. Of the work on carbohydrates, he said, "What all this work on carbohydrates means is not clear, at least to me. The only practical point seems to be that levulose is absorbed and probably utilized better than the other sugars."

Salts.—With regard to other constituents of the diet the retention of calcium and phosphorus is often poor, a fact shown by Holt, Courtney and Fales [61] and by McCrudden and Fales and demonstrated by our results (table 1) and those of MacCrae and Morris [62] of Glasgow. Sometimes indeed a negative balance for calcium and phosphorus has been found. The reason for the poor retention of calcium is not entirely to be found in the presence of large amounts of calcium soaps in the feces, but the impaired retention of both calcium and phosphorus also depends on the poor absorption of vitamin D consequent on the malabsorption of fat. The retention of both improves when vitamin D in a solid basis is administered. MacCrae and Morris believe that an alkaline reaction of the contents of the bowel is also a factor in this poor retention and found retention of calcium was improved by giving acid sodium phosphate (NaH_2PO_4). The question of the reaction of the bowel contents will be referred to later. Not infrequently also there is poor retention of other salts.

Protein.—The results of balance experiments with protein depend on the condition of the stool; in diarrheal periods the absorption of nitrogen is poor, although not to the same extent as fat, but in non-diarrheal periods it is quite satisfactory (table 2). Friese and Jahr [63] found 17.3 and 12.3 per cent of protein in the stools compared with 9.3 and 9 per cent in two normal controls, and Fanconi stated that the child with celiac disease eliminates up to 50 per cent of nitrogen in the stools, whereas in the normal child the figures are from 13 to 20 per cent.

CAUSATION OF CELIAC DISEASE

Various views as to the causation of celiac disease have been put forward from time to time, and the more important of these may now be considered and criticized.

Digestive Disorder.—The view that celiac disease is a digestive disorder has been held by most English writers from the time of Gee to within recent years. Gee does not commit himself to any cause but

61. Holt, L. E.; Courtney, A. M., and Fales, H. L.: Fat Metabolism of Infants and Young Children: III. Fat in the Stools of Children on a Mixed Diet, Am. J. Dis. Child. **18**:107 (Aug.) 1919.

62. MacCrae, O., and Morris, N.: Arch. Dis. Childhood **6**:75, 1931.

63. Friese, R., and Jahr, J. M.: Jahrb. f. Kinderh. **110**:205, 1925.

speaks of the disorder as a "kind of chronic indigestion," and apparently he was not quite convinced of the correctness of the suggestion that the pallor of the stools was due to "lack of bile." Cheadle, on the other hand, regarded the condition as essentially due to a cessation of bile secretion, and other writers have thought that either the liver or pancreas was at fault. Some have reported the absence of bile salts, but a large number of examinations of the stools in cases under my care has not yet revealed the absence of either bile pigments or bile salts.

Bile: Bile obtained by duodenal intubation has always shown the presence of bile salts and pigments, but it has to be borne in mind that the means available for the estimation of bile acids are indirect and afford no information as to the relative distribution of the different acids. One of the bile acids, deoxycholic acid, occurs either free in bile or in combination with glycine or taurine, and according to Wieland and Sorge,[64] forms stable molecular compounds with the higher fatty acids; further, the choleic acids isolated from bile are a mixture of such stearic, palmitic and oleic acid compounds, the sodium salts of which are soluble in water. This power of uniting with insoluble substances to form soluble products was called by Wieland, "the choleic acid principle," and he concluded that deoxycholic acid had an important function in transporting insoluble substances such as fats and fatty acids through the intestinal wall. According to Gardner and Gainsborough,[65] this "choleic acid principle" provides a more satisfactory explanation of intestinal fat absorption than either the theory of particulate absorption or that of the absorption of fats in the form of soluble soaps. Criticism of the view that fats are absorbed as soluble soaps has also appeared recently in a paper by Verzàr and Kúthy,[66] in which they claim to show that the absorption of fat from the intestine cannot take place in the form of soluble soaps because the reaction of the small intestine is slightly acid or neutral and soaps are unstable at p_H 7.2 or less and, further, that fat can only be absorbed in a water soluble diffusible form. They also found that the combinations of taurocholic and glycocholic acids with the higher fatty acids dissolved clearly in water and were stable not only at this p_H but even at p_H 6.26, and that such solutions could easily diffuse through parchment membranes.

In view of the "choleic acid principle," we have carried out some experiments to discover, if possible, whether there is in celiac disease any lack of deoxycholic acid. Two groups of experiments were therefore planned:

(1) An estimation of the fat balance in celiac disease during three metabolism periods

(a) On a basal diet

64. Wieland, H., and Sorge, H.: Ztschr. f. Physiol. Chem. **98**:1, 1916.
65. Gardner, J. A., and Gainsborough, H.: Quart. J. Med. **23**:465, 1930.
66. Verzàr, F., and Kúthy, A.: Biochem. Ztschr. **205**:369, 1929.

(b) On the basal diet with the addition of deoxycholic acid ("degalol" [Riedel])

(c) On the basal diet with the addition of the keto-acid, dehydroxycholic acid ("decholin" [Riedel])

(2) A comparison of the diffusion rate of a mixture of oleic acid and bile from a child with celiac disease with that of the same fatty acid and bile from a normal child

It was found that the fat balance was not improved by the addition of deoxycholic or dehydroxycholic acids (table 2) and that the diffusion rates of the mixtures of bile and fatty acids were the same in both cases. The results of these experiments, which are admittedly few, therefore show that the bile of the child with celiac disease is not different from that of the normal child, and we have therefore assumed that there is no deficiency in deoxycholic acid.

The gallbladder empties its contents into the duodenum either (*a*) by tonic contraction during the intermitent relaxation of the sphincter of the papilla as a peristaltic wave passes along the duodenum, or (*b*) as the result of active contractions produced by a chemical stimulus. The latter is almost certainly the correct explanation, the chemical stimulus being of the nature of a hormone. Ivy and Goldberg [67] isolated from the duodenal mucous membrane a secretin-like substance which is probably the hormone in question. Experimentally, the flow of bile can be increased by the application of 0.4 per cent hydrochloric acid to the duodenal mucous membrane or by the intravenous injection of "secretin" or bile salts. Now MacCrae and Morris regard the elaboration of the stimulus to bile production as the result of the action of the acid of the gastric juice on the intestinal epithelium and actually they call it "secretin." Further, they postulate in celiac disease an alkaline condition of the intestine which results in a deficiency in bile secretion and therefore of bile salts, and this apparently is their conception of the underlying cause of the disorder. The only evidence that they have to offer in favor of this hypothesis is that the giving of an acid salt (NaH_2PO_4) results in an increased absorption of calcium. Although it is true, as we shall see, that achlorhydria may occur in celiac disease, yet the contents of the duodenum are certainly not alkaline for Neale found that such contents removed by duodenal intubation have a normal p_H, being in fact about 6.9, an observation that fits in with the statements of Verzàr and Kúthy. It is also interesting to note that whereas bile in the hepatic ducts has a p_H of 7.7, it becomes slightly acid in the gallbladder, having a p_H of 6.8; moreover, the optimum reaction for the action of the pancreatic enzymes is from p_H 6.6 to 6.9, that is, a slightly acid medium and not alkaline as previously thought.

67. Ivy and Goldberg, quoted in Starling, E. H.: Principles of Human Physiology, ed. 5, Philadelphia, Lea & Febiger, 1930.

Pancreatic Juice: The pancreatic juice is poured out into the intestine as the result of a twofold stimulus: (1) reflexly through the vagus which results in the production of a small amount of fluid containing the enzymes—"vagal juice," and (2) by the hormone "secretin" which produces a copious flow of alkaline juice without ferments the function of which is to adjust the chyme to a p_H of 6.6 to 6.9. When there is gastric anacidity, as in many cases of celiac disease, very little "secretin juice" is required, but "vagal juice" is secreted normally; indeed, even in the achylia of pernicious anemia, it has been found that "vagal juice" is secreted and that this contains all the enzymes in normal amounts (Neale and Klumpp [68]). In celiac disease the pancreatic juice is normal because the fats in the stool are split normally; furthermore, specimens obtained by duodenal intubation have shown the presence of trypsin, amylopsin and lipase in normal amounts—indeed, the latter was sometimes present in more than normal amounts—when estimated by

TABLE 2.—*Ineffectiveness of "Decholin" and "Degalol" When Added to the Basal Diet of a Child, Aged Eight Years, Suffering from Celiac Disease*

Period of Observation	Diet	Weight of Dried Feces, Gm.	Percentage of Water	Percentage of Dried Feces				Daily Output of Fat, Gm.
				Total Fat	Saponified Fat	Free Fatty Acid	Neutral Fat	
4 days	Basal diet*.....	24.5	84	32.0	11.8	12.6	7.6	7.5
9 days	Basal diet and decholin....	22.0	78	43.5	13.5	16.3	13.7	9.4
11 days	Basal diet and degalol.....	22.0	87	42.6	14.9	17.9	9.8	9.2

* The basal diet in this case was selected from mince, eggs, chicken, rabbit, lean meat, green vegetables, banana, jam, honey, jelly and milk (skimmed).

the method of McClure, Wetmore and Reynolds. Bauer also found all these ferments present in a case of celiac disease in similar quantities to those found in a normal control child.

These observations on the pancreatic enzymes are directly contradictory of the statement by Fanconi that the diastatic ferments function poorly.

Gastric Juice: Achlorhydria has been reported in a large number of instances in children suffering from celiac disease. The significance of this finding has perhaps been overestimated, at any rate so far as celiac disease is concerned. Achlorhydria occurs in children under various conditions; thus Faber,[69] working with Bloch at Copenhagen, never found achlorhydria in normal children but observed it frequently in the acute infections of childhood and noticed that it might persist for months after recovery from such an illness. He regarded the

68. Neale, A. V., and Klumpp, P. G.: J. Clin. Investigation **9**:200, 1930.
69. Faber, K.: Lancet **2**:901, 1927.

condition as the result of a hematogenous toxic gastritis. Chevitz,[70] using the barley gruel test meal, found that of fifty-three children who suffered from digestive troubles one-half had achlorhydria and all showed low acid values. Furthermore, we [25] showed that achlorhydria in infants and children may depend on the type of test meal used or on the presence of parenteral or enteral infections, and that a lowered secretion of hydrochloric acid is common in artificially fed infants, particularly in those who are underweight or sick. To eliminate the variations in the quantity of free acid depending on the test meal, Neale [71] used from 20 to 40 cc. of neutral 7 per cent ethyl alcohol in distilled water, introduced through the Rehfuss tube, the resting juice which collected while the stomach was at rest having previously been removed. With this stimulus for gastric secretion, gastric juice without free hydrochloric acid has been obtained in some cases of celiac disease.

Achlorhydria and achylia gastrica are sometimes used as interchangeable terms, but the conditions are fundamentally distinct. Achlorhydria, which means absence of free hydrochloric acid, is, as already stated, of little real importance; whereas, achylia, which indicates complete absence of any secretion of hydrochloric acid or indeed of gastric juice at all, is of very great importance and its presence in celiac disease would be an additional argument in favor of the view that celiac disease and sprue are allied diseases, because true achylia gastrica has been found in the latter disorder (Fairley [72]). Achylia in celiac disease has been reported by Bloch, but I think that he used the word achylia as a synonym for achlorhydria. The only really adequate test for differentiating achlorhydria from achylia is the effect of subcutaneous injection of histamine, which results in the appearance of free hydrochloric acid in achlorhydria but not in achylia. Now in every instance of achlorhydria in celiac disease in which we have applied this test free hydrochloric acid has been obtained. It may be also of interest to note that in a series of about two hundred infants and children whom we have now examined by the fractional test meal we have never found any evidence of achylia gastrica. The gastric enzymes in a few cases of celiac disease have also been investigated by Neale, who found them present in normal amounts.

It will, therefore, I think, be admitted that our results do not show any evidence that there is any abnormality of the digestive juices in celiac disease, but rather the contrary.

Chronic Enteritis.—The conception that celiac disease is due to an enteritis owes its origin to Herter, who thought that the failure in fat absorption was due to an inflammatory disease of the intestine, which

70. Chevitz, I.: Acta paediat. **1**:416, 1921.
71. Neale, A. V.: Arch. Dis. Childhood **5**:137, 1930.
72. Fairley, N. H.: Tr. Roy. Soc. Trop. Med. & Hyg. **24**:131, 1930.

in its turn was due to the persistence and overgrowth of the intestinal flora of the nursling period. He drew attention to the fact that as long as an infant remains on an exclusively milk diet the organisms present in the stool are all gram-positive, but that once a mixed diet has been taken the bacterial character of the stool changes completely and the predominant organisms are then gram-negative. In celiac disease, however, he found a preponderance of the acidophilic gram-positive organisms characteristic of the nursling period, particularly B. bifidus and an organism which he called B. infantilis. While it is true that gram-positive organisms do predominate in the stools of children suffering from celiac disease, the conclusions of Herter have not met with general acceptance, although in 1925, Brown and his co-workers [73] came to the conclusion "that a predominantly gram-positive aciduric intestinal flora of B. bifidus type is characteristic of chronic intestinal indigestion," and that such a typical intestinal flora, unusual for the period of life at which celiac disease occurs, is strongly suggestive of a bacterial influence in its etiology. Since Herter's time, others have suggested that the condition was due to a chronic infection with organisms of the dysentery group, especially the Shiga and Flexner types. Occasionally, it is true, such organisms have been isolated from the stools, and in common with other observers we have found that the blood of children with celiac disease will sometimes agglutinate one or other of these organisms. It should not be forgotten that such positive agglutinations are sometimes obtained with the blood of children who are not suffering from any obvious intestinal disorder, and these results are so difficult of explanation that they cannot be accepted as sole evidence of cause and effect. Furthermore, if any group of children with celiac disease are examined for the presence of these agglutinins, the incidence of positive findings is no greater than in a similar group of normal children.

Moreover, celiac disease can be differentiated clinically from chronic enteritis. For instance, the onset of celiac disease is usually insidious and does not follow an attack of acute diarrhea. Again, the stools show different characteristics, for although the fat loss in the stool is increased in diarrhea it is not increased to such an extent as in celiac disease, in which, as a matter of fact, diarrhea is not so characteristic a feature as the passage of two or three loose stools in the twenty-four hours. But far and away the most important evidence against this view is the fact that postmortem examinations on proved cases of celiac disease have failed to show any sign of an acute or chronic enteritis.

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73. Brown, Alan; Courtney, A. M.; Davies, G. A., and MacLachlan, I. F.: Etiology of Chronic Intestinal Indigestion, Am. J. Dis. Child. **30**:603 (Nov.) 1925.

Celiac Disease in the Child the Same as Sprue in the Adult.—Within recent years, since renewed interest has been taken both in sprue and celiac disease, the similarity between the two diseases has furnished ground for much comment and recalled to mind the observations of Gee in his original paper. Gee wrote, "Sometimes from India Englishmen return sick with the coeliac affection; seldom is it met with in adults who have never left our island." Thaysen, among others, drew attention to the fact that instances of fatty diarrhea associated with extreme wasting and tetany occur sporadically in temperate regions. These cases he calls nontropical sprue and groups them with sprue and celiac disease under the one title of "idiopathic steatorrheas," regarding them all as manifestations of the same disease, a view that Hunter in his Goulstonian Lectures apparently accepts. There is unquestionably a marked similarity between the clinical picture of sprue and that of celiac disease; thus in each there is distention of the abdomen, the passage of bulky fatty stools, at times diarrhea, the occurrence of tetany associated with a diminished concentration of calcium in the blood, a low blood sugar curve, an abnormal condition of the tongue and achlorhydria and anemia. Indeed, at first sight the two diseases might be regarded as identical, but on closer examination there are essential differences. Thus, while it is true that the achlorhydria is frequent in both diseases, true achylia has never been found in celiac disease, although it has not infrequently been demonstrated in sprue; for instance, Fairley found achlorhydria in seven of eighteen cases of sprue, and of these five cases showed true achylia, since there was no acid response to the injection of histamine. Further, the anemia of celiac disease is a secondary anemia comparable with the nutritional anemias of infancy and rarely, never in my experience, shows any megaloblastic characters, whereas practically all patients dying of sprue present a megalocytic anemia of grave type, and in the large majority of cases there is evidence of a megalocytic response on the part of the bone marrow. In Fairley's series of twenty-eight cases of sprue, twenty-two showed anemia of which nineteen were proved to be megalocytic when the red blood cells were measured by Eve's halometer. The outstanding characteristics of the blood film were anisocytosis with an excess of megalocytes; punctate basophilia, normoblasts and even megaloblasts were found in those severe cases in which the red cell count fell to under 2,000,000 per cubic millimeter. In eighteen cases the color index ranged from 1.0 to 1.5. Now, in children above the age of infancy megalocytic anemias are very rare and, as I have stated, have not been observed in our series nor have we seen any reticulocyte response to liver therapy in the anemia of celiac disease, whereas such a response does occur in sprue.

Another interesting feature is that sprue practically never occurs in childhood, and on the other hand, Fairley informs me that during his

four years experience at the St. George's European Hospital, Bombay, he never saw a case of celiac disease. Here again, however, we get considerable help from morbid anatomy, for in sprue there are present an atrophic enteritis and a megaloblastic and aplastic condition of the red marrow, changes that have never been observed in celiac disease. One may therefore dismiss, I think, the suggestion that celiac disease and sprue are the same disorder. It is true that many of the symptoms are similar because of the fact that in each the malabsorption of fat is an essential defect, but because of this to suggest that they are the same disease is much the same as to suggest that diabetes and renal glycosuria are the same condition because glycosuria is found in both instances.

Infective Obstructive Lesion of the Lacteal Tree.—The theory that celiac disease is due to an infective obstructive lesion of the lacteal tree has already been adequately dealt with.

Metabolic Disorder Similar to Diabetes.—The theory that celiac disease is a metabolic disorder similar to diabetes is based on the researches of Hill and Bloor, Bloor and Sperry, and on certain findings with regard to blood fat, has also been discussed and discarded.

Deficiency Disorder.—Concerning the view that celiac disease is a deficiency disorder, Morse remarked:

> In this day and generation when one cannot open a newspaper or lay magazine or turn on the radio without seeing or hearing something about vitamins, it was impossible that this symptom complex should not be supposed by some to be the result of an avitaminosis.

In the course of an investigation carried out by McCarrison, it was found that monkeys fed on a diet deficient in vitamins, but containing an excess of carbohydrates and fats, developed a general appearance very like that of celiac disease and passed fatty stools which became of normal color after the administration of vitamin extract. Peters [74] in his Harben Lectures (1929) brought forward some evidence to show that one of the factors of vitamin B is concerned with fat metabolism. Whether or not an avitaminosis is the true explanation of the change in alimentary function cannot be stated, but there can be no shadow of a doubt that a defect, not in the supply but in the absorption, of vitamins resulting from the impaired alimentary absorption is the cause of many of the most characteristic symptoms of the disorder, a fact which, of course, has a most important bearing on treatment.

Endocrine Deficiency.—The theory that celiac disease is an endocrine disorder, so far as it bears on carbohydrate metabolism, has also been discussed and reasons given for rejecting it. In view of the results of

74. Peters, R. A.: J. State Med. **38**:63, 1930.

a single autopsy, Schick and Wagner regard celiac disease as a pluriglandular insufficiency, but as described in the section on morbid anatomy there is more than one case on record in which examination of the ductless glands has revealed no abnormality. The remarks of Morse on this theory are also very refreshing:

> This symptom complex has been attributed, of course, as everything is sooner or later, to a "dysfunction" of the endocrine glands. Since no one knows what these glands, with a few exceptions, do or do not do to the system as a whole or to each other, it is very easy to lay any symptom at their door. It is equally hard either to prove or disprove any claims or statements which are made regarding them. As far as I am able to find there is no convincing clinical or experimental evidence either on one side or the other—merely assumptions, guesses and conjectures.

After such a criticism it would appear that there is nothing more to be said or done except perhaps for its followers to drop a few silent tears of regret on the dead body of the endocrine theory.

I am sorry that after so much destructive criticism I have no positive solution to offer, but it is no use adopting phrases such as that used by Friese and Jahr to the effect that this disorder is a neurosis of the vegetative nervous system, to hide the fact that the cause of celiac disease is not yet known; rather it is far better to admit ignorance. I must admit that I am always hazy as to the meaning of the term "vegetative neurosis," but these writers base their statement on the fact that by roentgenographic examination they had observed that food rapidly passed through the stomach, small intestine and the beginning of the colon, thereby not allowing time for absorption, and that the administration of opium in two cases, by slowing the peristalsis, produced great improvement. I trust, however, that in this discussion I have demonstrated that there is defective absorption of fat and carbohydrate and that of these the defective absorption of fat is of primary importance, but if I am asked the why and the wherefore of this faulty absorption, I am at present unable to give an answer. Nevertheless, remembering the results of the investigations I have set before you, the absence of morbid findings and the fact that the disease may cure spontaneously, it seems logical to assume that the defect belongs to the so-called "functional" disorders, and that, although up to the present no change has been found in the intestinal secretions, the probable explanation of celiac disease lies in a change of a physicochemical nature in the absorptive mechanism of the intestine.

Morse expressed the belief that it is wise to think of celiac disease as a severe type of chronic indigestion differing only in degree from everyday minor disturbances, and that it is a manifestation of a serious impairment of the digestive and absorptive powers for fat and carbohydrate, especially starch. He regarded it as a mistake to give this symptom complex a name and said that it will be time to do this when a

specific etiology and pathology are established for it. While it is true that there are varieties in severity of the disorder, the whole clinical picture is so characteristic and unlike that seen in any other nutritional disorder of childhood that I think its existence as a "clinical entity" should be accepted. If so, why not give it a name? Surely the clinician has often worked in this way, first giving a name to an entity and later finding the cause. After all, juvenile acrodynia (pink disease) is, I believe, universally admitted to be a disease and yet its etiology and pathology are unknown.

TREATMENT

Gee wrote, "If the patient can be cured at all it must be by means of diet," but the particular form of dieting has varied with the passing of the years. Gee believed that milk was the least suitable form of all food, and that there was "nothing more certain than that celiac children cannot digest the hard curd of ruminant's milk." He therefore gave raw beef or underdone mutton and substituted asses' milk for cow's milk whenever possible. Asses' milk, which is characterized by its low fat content (1 per cent) and the fact that of its protein content (1.8 per cent) nearly half (0.8 per cent) is lactalbumin, has also been recommended by Still. Herter, however, found a strictly protein diet very beneficial, and this he attributed to the effect of the protein on the intestinal flora; fats were, he thought, on the whole better tolerated than carbohydrates. Heubner, in 1909, also emphasized the importance of a high protein, low carbohydrate and low fat diet. Lichtenstein and Still both found that breast milk was the best substitute for cow's milk, a fact which is borne out by our metabolism studies. Still stated that fresh cow's milk is to be entirely forbidden, and that many patients have done well for years on dried milk as their main article of diet.

The greatest advance in the treatment of this disease was the adoption of Howland's three stage dietary, which surely needs no introduction to an American audience. Possibly, however, some of his arguments for the use of this diet may be recalled, thus he wrote:

> From clinical experience it has been found that of all the elements of the food carbohydrate is the one which must be excluded rigorously; that with this greatly reduced the other elements are almost always well digested, even though the absorption of fat may not be so satisfactory as in health. It may perhaps be permissible to liken the treatment of this disease to diabetes. In the one there is intestinal intolerance, in the other an endogenous intolerance to carbohydrates. The tolerance of the diabetic is diminished by an overstrain and so is the tolerance of the intestine. In either case the tolerance tends to increase if it is guarded from strain. The diabetic is doing badly when there is sugar in the urine. The child with chronic intestinal indigestion is doing badly so long as his distension continues and his stools are foamy and not firm, even in the absence of more serious diarrhoea. A catastrophe is bound to occur sooner or later. The indication is to give such a food that the stools become homogeneous and formed, disregarding, it may be for the moment, any consideration of weight.

The dietary treatment may be divided into three stages. First, that with protein milk alone.

> . . . It should be continued until the stools are firm, the distention very slight, the gas not in excess and the appetite good . . . a matter of days or a few weeks. The diet of the second stage consists of protein milk as a basis reinforced by almost pure protein foods. . . . The duration of this stage is many months, it may be years. The third stage, that in which carbohydrates are added, is the really difficult one. The addition must be made very gradually with the most careful observation of the digestive capacity.

His concluding remarks in this three-phase diet are:

> Half-way measures are quite unavailing and cause only loss of time, which is a serious matter for the time required for a cure is years. The patience of everyone is taxed to the utmost.

I have only one criticism to make of this diet and, knowing Howland's rare clinical ability and thoroughness, I do so with bated breath. The criticism is that in framing this diet there is not sufficient attention paid to the malabsorption of fat. Since the war, in a series of papers, Miller has stressed the importance of fat reduction in the diet of children with celiac disease. The exclusion of all fat is not advocated, but an attempt is made to frame a diet that contains the optimum amount of fat consistent with satisfactory growth and a complete absence of symptoms; indeed, Miller pointed out that some children thrive better if allowed small amounts of fat, and wrote, "it is unwise to treat the stools and not the patient." On the other hand, he does not stress so much as I think he should the importance of the reduction of carbohydrates. I have found that the best results have been obtained by a combination of the two suggested lines of dieting. I would say, therefore, that the essentials of dietetic treatment are a high protein diet with a very low fat content; no carbohydrates until considerable improvement has occurred, and then only limited amounts; an adequate supply of vitamins, salts and water. These essentials are best met by a three phase dietary similar to that of Howland but keeping the amount of fat greatly reduced. Sauer also makes the same observations, but in his papers I notice that he allows more fat than we do.

In our dietary the first phase is to give a protein skimmed milk prepared by using a good dried skimmed milk powder to which is added protein in the form of calcium caseinate (the brand manufactured by Mead Johnson and Company) in the proportion of 20 grains (1.3 Gm.) to each ounce of reconstituted milk and which is, if necessary, sweetened by the addition of saccharine. The second phase consists in the addition of bovril—or other form of beef juice from which the fat has been removed—and other varieties of protein such as the white of egg, curds made from skim milk, small quantities of rabbit or breast of

chicken. In the third phase, the amount of protein is increased and small amounts of carbohydrate are added; these take the form of ripe banana, zwieback, grape nuts and potato crisps made without fat; finally, well cooked cereals such as rice and arrowroot, and small amounts of fat, are permitted.

All dietetic modifications call for the greatest watchfulness, and care should be taken to notice any slackening in the gain of weight; any increase in abdominal distention or in the frequency and offensiveness of the stools, the occurrence of pyrexia, irritability, etc. This care applies particularly to any addition of fat to the diet, since, as already stated, some of these children react so rapidly to fat as to suggest an allergy. In any case it is probably unwise to return to whole milk for at least a year after commencing adequate treatment, but cases vary so much that it is impossible to lay down rigid time intervals. When increasing the amount and variety of protein given to the child, it is wise to remember that lean meat contains a good deal of fat and that tongue, which has been recommended so freely as a good source of fat-free protein, contains fat in more than appreciable amounts; indeed, as far as our experience goes, the meat which presents the nearest approach to freedom from fat is rabbit, and second to it the breast of chicken.

If at any time during treatment there is any recurrence of untoward symptoms, the first phase diet must at once be resumed. The addition of many forms of carbohydrates increases the frequency of the stools, but this is less likely to occur if dextrinized flours are used, or if the carbohydrate is given as grape nuts, or thoroughly toasted, almost caramelized bread, such as zwieback, or thin slices of potato treated in the same way. As indicated several times in these lectures, and largely owing to the advocacy of Haas, many people now make use of the pulp of thoroughly ripe bananas. Morse's comment on this line of treatment is that since the publication of Haas original article in 1924, "with one or two exceptions the articles on this subject in the American medical literature have read like advertisements of the United Fruit Company." The banana must be fully ripened, in which condition the skin is dark brown, thin and can be stripped from the fruit with great ease. The chemical composition of banana pulp is as follows: protein, less than 1 per cent; fat, nil; ash, 1 per cent; carbohydrate, 20 per cent, and when thoroughly ripe all the carbohydrate is in the form of invert sugar. Iron, phosphorus, calcium, magnesium and vitamins A, B and C are also present, so that in theory it is a highly valuable foodstuff and in practice also it is found to be useful in many cases, but in others leads to increased frequency in the number of the stools, an effect which may sometimes be due to the difficulty in England in obtaining the fully ripened fruit.

With regard to vitamins, until recently, except for sporadic attempts to supply vitamin A by the subcutaneous injection of a concentrate, we have not attempted to give this vitamin, but in our recent cases we have tried the effect of administering carotene as a source of this vitamin. Mellanby estimated that 1 mg. of carotene daily constitutes an effective dose. Carotene, as its name implies, is derived from carrots, "so that the donkey is not such an ass after all." Now it takes 1 ton of carrots to make 1 grain of carotene, and at the present cost of carrots in England this works out at about one penny (two cents) for 1 mg. of carotene. Vitamin B is supplied by the administration of yeast or an autolyzed yeast concentrate, and vitamin C by orange juice. It is essential to supply vitamin D, either by ultraviolet radiation or by the administration of viosterol in a dry and not an oily form, or by both these methods, for such treatment, consistently carried out, will prevent the development of rickets. If rickets has already developed, its cure will require large doses of these measures, and it is important to remember that to obtain a cure treatment is usually necessary for a much longer time than for the cure of infantile rickets.

Before dealing with other points in treatment, reference must be made to a dietetic treatment carried out by Fanconi of Zurich. This is a fruit and vegetable diet, the basis of which is finely divided bananas, apples, pears, orange and lemon juice. Finely ground almonds and other nuts are soon added, and then finally grated steamed or raw vegetables. The acidity of the fruit is neutralized by the addition of precipitated chalk. Protein is then added in the form of buttermilk, cottage cheese and lean meat. It is said that diarrhea and loss of weight may occur in the first few weeks, but that such children gain weight when the protein is added to the dietary. Fanconi reported excellent results by this method of treatment, but it is one with which I have not had any experience and Morse said of it "I should hate to try it." Rest in bed is of great importance in the early stages of celiac disease, as indeed it is at any time if the disease shows severe manifestations or active rickets. The greatest care should be taken to prevent parenteral infections, and in severe attacks of diarrhea periodic blood transfusions are of the greatest value and in a bad case may prove the turning point in the illness. Gentle massage to the limbs is helpful, particularly during the period of confinement to bed. For the anemia, liver extract has been tried but without much success, a result to be expected in view of the nature of the anemia; the drug which has proved most useful in our experience is ferrum redactum in 1 grain (0.065 Gm.) doses, and the reason for this is probably that in addition to the iron, copper is always present as an impurity. Other drugs are of little or no value, and the administration of pancreatic extracts is based on an incorrect conception

of the disease. In some instances the administration of bile salts has seemed to be of some value; Miller, in particular, advocated their use and said that he has seen them turn a diarrheic into a nondiarrheic case. I am doubtful whether it is not the dietetic treatment that is actually the cause of improvement and not the administration of bile salts, especially as we have never found the bile salts absent in any case in which their presence has been tested for. Nor has the administration of pituitary or thyroid extracts made any difference to the course of the disease. Smith [75] reported marked improvement in two patients who were given a mixed diet and 2½ units of insulin daily. These cases are insufficient and the dose of insulin too small to quote as evidence in support of insulin therapy, although Budde [76] was of the opinion that insulin is useful because it favors absorption of water from the intestine.

The treatment of celiac disease is very tedious and full of anxiety because it is so prolonged, lasting sometimes for years, and progress is so slow; at times there are bad, even catastrophic, setbacks, hence, unless there is hearty cooperation and the "will to conquer" on the part of parents and doctor, success will never be achieved. In spite of all this, the disease and its treatment have a peculiar fascination because by dogged perseverance and refusal to admit defeat an apparently hopeless invalid can be transformed into a useful member of child society, able on reaching adult years to take his or her allotted place in the world.

My task is almost over, and no one is more conscious than myself how inadequately I have discharged it, but believe me the fault lies in the lecturer and not in his subject. I regret that I have to leave future research to discover the cause of celiac disease, but if what I have communicated to you has narrowed the field of inquiry by clearing away some erroneous views and thus made the final issue clearer and simpler, I shall have accomplished some part at least of what I set out to do. If there has been anything new in these lectures, the credit for its discovery I shall gladly share with my colleagues, A. V. Neale and Miss E. M. Hickmans, who have freely lavished much thought and great industry on the problems presented. I am also greatly indebted to my friend, Dr. Kenneth Blackfan, of Boston, for putting the resources of his clinic at the disposal of A. V. Neale and for allowing us to make use of his cases, and to the Medical Research Council for defraying the cost of the investigations carried out at the Children's Hospital, Birmingham.

Finally, I wish once more to convey to the trustees of the Rachford Memorial Fund my deepest thanks for the great honor they have done me in appointing me to deliver the first Rachford Memorial Lectures.

75. Smith, Bellingham: Arch. Dis. Childhood **3**:177, 1928.
76. Budde, O., quoted by Marfan (footnote 52).

THE PHYSICAL GROWTH OF BOYS

A STUDY BY MEANS OF WATER DISPLACEMENT

DOTT EARL ZOOK, PH.D.

CHICAGO

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I. INTRODUCTION

STATEMENT OF THE PROBLEM

Progress in the field of measurements is dependent on the precision of the measuring devices used and on the ease with which these devices can be used effectively. Especially is it desirable in the study of physical growth that more exact measurements be secured than have been secured by the methods that have been employed in the past. Since the human body and its segments are three dimensional, methods of measurement must be adopted which express the relations of these segments in units of volume.

The purpose of this study is to present a precise method of measuring the volume of the human body. The method permits the measurement of the segments of the body and the expression of all the measures taken in units of volume. This method of measurement is presented not only as a research device to be used in the study of physical growth, but also as a practical method for use in school health work and in other fields of education.

Physical growth presents two aspects, the external and the internal. The external aspect is recognized as an increase in size or volume. The internal aspect consists in the many vital changes taking place within the body, such as the increase in the size of the heart and arteries and the percentage of muscle and bone. The present method of measurement deals with the external aspect directly. Since size is dependent on the more vital changes taking place within, it is believed that the present method can be used to determine or predict these internal changes.

Since the limitation of time prevented the making of successive measurements on a number of subjects, the method was applied to one hundred and sixty-four boys from 5 to 19 years of age. Two distinct types of boys were measured: a well nourished group from the University of Chicago Laboratory Schools and a group from the University Settlement in the Stock Yards district.

BRIEF SUMMARY OF THE PREVIOUS LITERATURE

A very few instances are found in which an attempt has been made to measure the volume of the human body or any of its segments. Instead of developing a precise and practical method of measuring body volume, formulas based on one or more variables, such as standing height, width of chest or sitting height, have commonly been employed. A few instances can be found in which water displacement was used in the study of the human body. None of the earlier methods was used in the study of physical growth; they were used to study the buoyancy of the body or to determine the size of artificial limbs.

Robertson.—As early as 1754, John Robertson (quoted by Mumford), master of mathematics at Portsmouth, England, had determined the specific gravity of the human body by the use of air bladders.

Wilkinson.—In 1764, Wilkinson (quoted by Mumford) again determined the specific gravity of the body by substituting cork for the air bladders. His work resulted in the introduction of the cork life-preserver jackets for sailors.

Godin.—About 1890, Paul Godin in France became convinced that if he could obtain the ratio between the volume of the cranium and the volume of the trunk, he would be able to predict, with great accuracy, the onset of puberty and other physical conditions. He computed the volume of both segments as if they were rectangular solids. From his measurements over a period of twenty years, in which he measured more than one thousand subjects in each age group from birth to maturity, he concluded that at birth the ratio of the cranium to the trunk is 74 : 100, and at the onset of puberty 20-23 : 100, depending on the body build at that time. By making repeated measurements on the same subject and determining the rate at which the ratio decreased, he claimed to be able to predict with exactness the onset of puberty.

Bean.—During the World War, Bean,[1] working with the American Red Cross to provide more balanced artificial limbs for disabled soldiers, used water displacement to obtain the volume of the artificial limb by submerging the corresponding whole limb in water and measuring the water displaced. The specific gravity was determined, approximately, by finding the specific gravity of the limb that had been amputated. Thus having the desired volume and the specific gravity, an artificial limb could be made the same size and weight as the corresponding whole limb, restoring the symmetry and balance of the whole body as they were before the loss of the limb.

1. This description of the work of Dr. Bean was furnished by W. R. Bean, Jr., a nephew, since the description of Dr. Bean's work was not available in published form.

Pirquet.—By 1917, Clemens Pirquet, working on a new system of nutrition, had evolved a formula for body volume based on the sitting height. The basis of this formula is explained by the originator as follows: "A cube one side of which is the sitting height—i.e., a cube in which the human being can sit upright—if filled with water would represent ten times the weight of the body; or in other words, this cube is capable of holding ten persons closely packed." He assumed that the specific gravity of the body is the same as that of water, and, therefore, that the weight of the body expressed in grams would equal the volume of the body expressed in cubic centimeters. His formula for weight based on sitting height is: "the sitting height (in centimeters) equals the cube root of ten times the weight (in grams)." Substituting volume for its supposed equivalent weight, the formula becomes: "the volume of the body is equal to the cube of the sitting height (any unit of length) divided by ten." Pirquet was not particularly concerned with the volume or weight of the body except in their relation to the sitting height. This relation gave him his desired "index of nutrition" or body build.

Mumford.—About 1925, Alfred A. Mumford, medical officer of the Manchester Grammar School for Boys, having weighed many boys in the swimming tank to obtain their specific gravity, evolved a formula for body volume so that he might determine the specific gravity from the measurements of the body without the necessity of weighing the body in water. From a comparison of the measurements and the specific gravity obtained, he assumed that: "the body volume is equal to that of a right cylinder having a diameter equal to the mean of the width and depth of chest, and an altitude equal to the height of the body" (p. 131). Having the weight of the body in grams, he had only to divide this weight by the weight of a volume of water equal to that of the body as found by the formula, in order to secure the specific gravity of the whole body. His assumption was directly against that of Pirquet; namely, that the specific gravity of the body is the same as that of water. Mumford was concerned with finding the natural buoyancy of the body for the information and guidance of the swimming instructor.

Franzen.—Raymond Franzen (in *Elementary School Journal*), of the American Child Health Association, stated that the human body must be regarded as a solid, having three dimensions instead of height alone. Like Mumford, he considered that other factors have as much influence on the size of the body as height, if not more. From many anthropometric measurements and their correlations with the weight of the body, he determined the relative value of these factors at various ages in determining the weight or size of the subject. For the 11 year

old boy, for instance, these are: girth 43, height 22, chest 15, hips 10, subcutaneous tissue 8 and shoulders 2.[2]

II. PLAN OF THE INVESTIGATION

METHOD OF SECURING DATA

Most of the data used in this investigation are measurements made by an apparatus constructed to give the volume of the body and its segments in cubic inches. Additional data were secured from certain anthropometric measurements made at the time measurements were made with this apparatus. Still other data, such as age or date of birth, were secured from the physical record cards of the Laboratory Schools and the records of the university Settlement and from the answers given to a number of questions put directly to the boys measured.

The Water Displacement Apparatus.—The measurements made by the water displacement apparatus are based on the time-honored principle of Archimedes: "the volume of water displaced by a body submerged is equal to the volume of the body," which is so self-evident as to need no further explanation.

The apparatus as finally constructed and used in this investigation is represented in figure 1. A heavy galvanized steel tank, 7 feet (215.4 cm.) deep and 24 by 16 inches (61 by 41 cm.), was constructed with heavy 2 inch (5 cm.) angle irons extending upward an additional 7 feet from each of the four corners of the tank for the support of the lowering device, on the platform of which the subject stands while being measured. The platform is supported by four one-half inch (1.27 cm.) steel rods extending from each corner of the platform to each corner of a square frame 6½ feet (198 cm.) above the platform. At each corner of the platform and the frame, rollers are adjusted to run in the inner angle of the supporting angle irons to avoid any undue lateral movement. The entire lowering device is supported by a three-eighths inch (0.95 cm.) steel cable running over a pulley at the top of the apparatus and over another pulley on the wall and thence down to a 4 ton self-locking hand hoist. Secured to the top of the lowering device is a gear rod 7 feet in length which engages a gear wheel at the top of the tank, causing the graph board to move to the left one fifth of an inch (0.7 cm.) for each inch the platform is lowered. On the inside of the tank at the left is a 1 inch (2.5 cm.) aluminum rod 7 feet in length. This rod

2. The relative value of the factors influencing size as given in the Elementary School Journal are: hips 30, depth of chest 26, width of chest 20, height 20 and width of shoulders 5.

is attached to the top of the lowering device by a piano wire running over a small pulley at the top of the frame in such a way that it is raised 1 inch for each inch the platform is lowered, thus exactly compensating for the four one-half inch rods supporting the platform, which displace water as they are lowered. On the front of the appa-

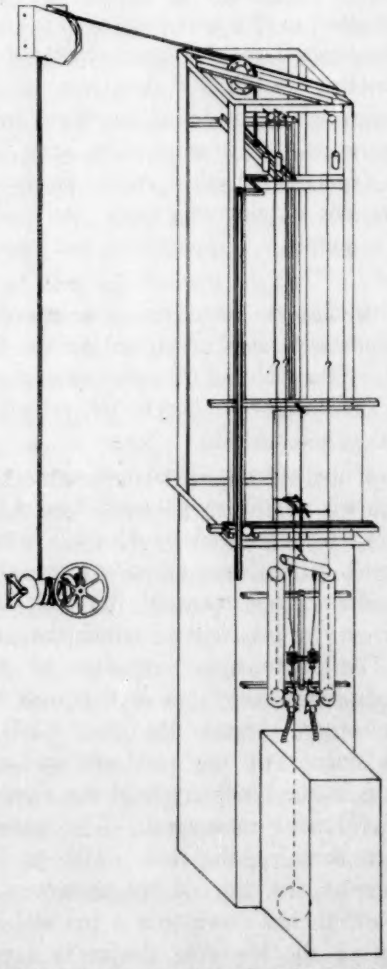

Fig. 1.—Water displacement apparatus for determining body volume.

ratus just below the graph board and 2 inches (5 cm.) from the top of the tank is the overflow pipe through which the water displaced is carried into either of the small brass tubes in which it is measured. These tubes are 24 inches (61 cm.) in length with an inner cross-section of 10 square inches (64.5 sq. cm.) Within each tube is a conical brass float with a counterbalanced rod extending upward, actuat-

ing the lower pen in front of the graph board, causing it to indicate the number of cubic inches of water discharged into the tube. The valves at the bottom of these tubes operate in such a way that the tube into which the water is being discharged is closed while the other is opened and discharges into the cumulative tank below, which is 3 feet (91 cm) deep and has an inner cross-section of 200 square inches (1,290 sq. cm.). In this tank is another brass float attached to a counterbalanced rod which actuates the higher pen in front of the graph board, causing it to record the total volume of all segments submerged. On the inside of the large tank at water level is suspended a rubber U tube through which the subject breathes while the head is under water. The open ends of the tube are above the water level, while the remainder of it is submerged so that it will cause no further displacement of water when used. At the back of the tank and opposite this breathing tube is a horizontal rod astride of which the subject stands while being lowered. When the body exerts a 2 pound (1 Kg.) pressure on this rod, it drops down, indicating the total length of the legs. Water is supplied to the tank of the apparatus through a hose attached to a mixer in front of the machine and is discharged through either of the two drains at the bottom of the tanks.

Graphs Made by the Apparatus.—Measurements made by the water displacement apparatus are recorded in the form of graphs on coordinate paper (16 by 21 inches [41 by 53 cm.]), with five or ten divisions to the inch. Since the graph board moves to the left as the platform is lowered, the height is indicated at the bottom of the graph with a zero point at the extreme left and each one fifth of an inch to the right, indicating an inch in height. Figure 2 is a reduced copy of the graphs made by the apparatus.

The graph at the bottom of the page is known as a profile graph, since it slightly resembles the human form. It indicates the cross-section area of the body at any point and is secured by lowering the subject 1 inch at a time. The water displaced when the subject is lowered the first inch is discharged into one of the small brass tubes, causing the float to rise and thereby causing the lower pen to move along the vertical coordinate one fifth of an inch from the left edge of the graph. Since the cross-section of the tube is 10 square inches, the pen is raised 1 inch for each 10 cubic inches (163.8 cc.) of water discharged into the tube. The total number of cubic inches indicated at any point is the cross-section area of the body at that point. The overflow is alternated between the tubes as the measurement continues. The way in which the pen moves up and down as the overflow alternates is illustrated near the center of the graph. When the pen reaches the highest point and the overflow is changed, the pen moves down, but

does not reach the bottom as it is caught by the float in the other tube, which is being filled. The profile graph has little practical value and requires nearly one hour for its completion. It is probable that the profile graphs of the two sexes will be markedly different, and the profiles for different races may show some differences. This graph is given here only to show in how great detail the apparatus records volume.

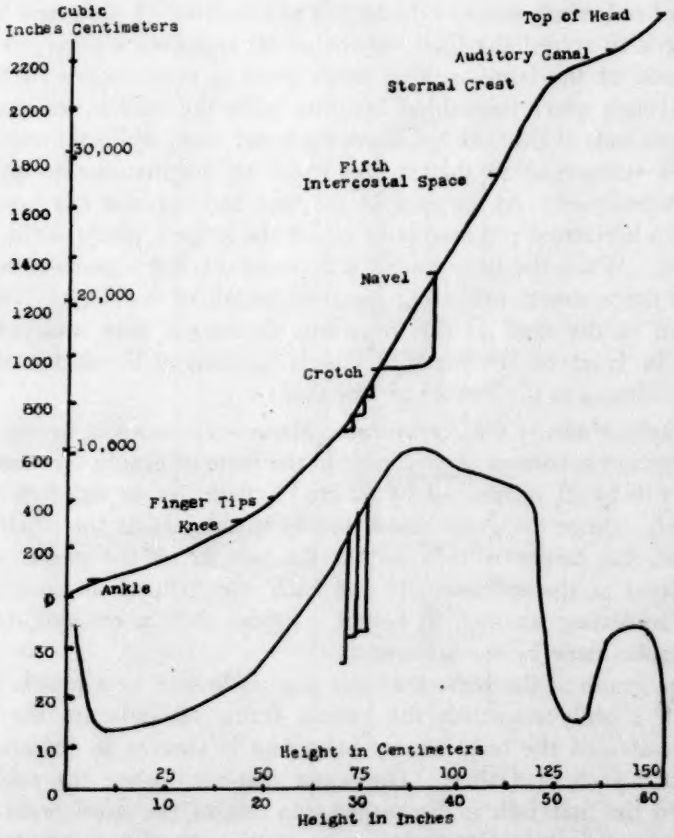

Fig. 2.—Reduced copy of profile and cumulative graphs made by the water displacement apparatus.

The cross-section area of the body, which may be read directly from the profile graph, may be secured from the cumulative graph, which is shown above it. This is done by measuring the vertical distance between any two points that are 1 inch apart on the horizontal and reading the measurement in the scale for volume at the left. The cumulative graph may be made at the same time as the profile graph, but is generally made alone as it requires only about eight minutes for its completion. When made alone the subject is stopped only at the division points between the segments; i. e., the ankle, knee, etc., the pen

moving as indicated by the irregular line between the crotch and the navel. When this graph is being made, the valve at the bottom of the small tube is opened so that the overflow discharges directly into the cumulative tank at the bottom of the apparatus. Since the cross-section of this tank is 200 square inches (1,290 sq. cm.), the float causes the pen to rise 1 inch for each 200 cubic inches (3,275 cc.) of water discharged into the tank. When the subject has been lowered to the division point and the water has stopped overflowing, the subject is raised slightly so that a horizontal mark is made to the left of the graph, indicating the division point. The length of any segment is found by taking the horizontal distance between two division points in the scale at the bottom for height. The volume of any segment is found by taking the vertical distance between two division points in the scale at the left for volume.

Individual Data Sheet No. 12

Name....., ... Date 10/10/'29 Time 10 a. m.

Age, 12 years, 121 days. Shoe size, 7½C A. Height in air, 61 inches (155 cm.); submerged, 61.2 inches (155.5 cm.). Variation, 0.2 inches (0.5 cm.). Sitting height, 30.7 inches (78 cm.). Weight, 91.6 pounds (41.6 Kg.). Weight of water displaced, inhale, 92.3 pounds (42 Kg.), exhale 85.9 pounds (38.9 Kg.). Specific gravity, inhale, 0.992; exhale, 1.066. Chest, width 9 inches (23 cm.), depth 5.3 inches (13.4 cm.). Lung capacity, 175 cubic inches (2,862 cc.). Volume of arms, 188 cubic inches (3,079 cc.).

	Volume			Length		
Segment	Cm.	Inches	Per Cent	Cm.	Inches	Per Cent
Foot	1,146	70	2.9411	6.6	2.6	4.2483
Calf	3,930	240	10.0840	38.1	15.0	24.5098
Thigh	10,154	620	26.0504	35.9	14.1	23.0392
Total leg	15,231	930	39.0756	80.5	31.7	51.7973
Loin	6,387	390	16.3865	14.7	5.8	9.4771
Abdomen	6,551	400	16.8067	15.5	6.1	9.9673
Chest	6,551	400	16.8067	15.0	5.9	9.6405
Total trunk	19,489	1,190	50.0000	45.2	17.8	29.0849
Neck	1,801	110	4.6218	15.8	6.2	10.1307
Cranium	2,457	150	6.3025	14.0	5.5	8.9869
Total head	4,258	260	10.9243	29.7	11.7	19.1176
Total body	38,980	2,380	99.9999	155.5	61.2	99.9998

Volume by Mumford's formula: 2,482 cubic inches (40,643 cc.). Variation: 102 cubic inches (1,670 cc.).

Volume by Pirquet's formula: 2,893 cubic inches (47,379 cc.). Variation: 513 cubic inches (8,401 cc.).

Individual Data Sheets.—An individual data sheet used to record the readings taken from the graph as well as the data procured from the subjects or from their physical records is shown in the following section. Space is also provided to record the computations made for the various items included.

Computations.—After the volume and the length of each segment had been taken from the graph and recorded on the data sheet, computations of the percentage of total volume and percentage of total length were made to four decimal places. In making all of the tables used in this study, the four decimal places were not used but were shortened to the nearest 0.1 per cent. When all individual data sheets had been filled out and checked, they were arranged according to age in the group to which they belonged, as shown in the Appendix. Each age group was made to include all cases within six months of the exact year. The 12 year group, for instance, included all cases from 11 years and 6 months to 12 years and 6 months. The mean of each age group and for each subgroup was then computed for each of the items appearing on the individual data sheet.

SELECTION OF SUBJECTS

In this investigation the subjects were limited to boys, because it was believed that they would more readily undertake the measurement than would girls. Also, the boys could be measured in the nude and thus avoid the slight error caused by the wearing of a bathing suit.

Originally, it was intended that only boys from the University High School would be used in this study. Three hundred and sixty requests were mailed to parents explaining the nature of the measurement and asking permission to measure their sons. One hundred and two permissions were granted. When the measurements were begun, it was found that a number of the boys for whom permission had been secured could not be measured. Ninety-five boys of this group were measured, and the group is designated throughout the study as the "University Group."

On account of the small number of subjects that could be secured from the Laboratory Schools, another group of sixty-nine boys from the University of Chicago Settlement, in the Stock Yards district, was measured. It was believed that by comparing the two groups the effect of poor food and improper care on the various segments of the body could be pointed out. None of this group was in the high school, although many were of high school age. This group is designated as the "Settlement Group" throughout the study.

The total group studied included boys from 5 to 19 years of age. However, the number of subjects in the age groups at either end of the distribution is so small that little significance can be attached to their measurements. Only one case is found in each of the following age groups: 5, 7, 8, 18 and 19. Two cases are found at 6 and three cases at 9. The other age groups vary from eight to thirty-seven subjects.

SEGMENTS CHOSEN

The segments chosen were those that appear to be the most natural divisions of the body where a division point between the segments could be located with as little variation as possible. These segments, in the order in which they were measured, are as follows:

1. The foot, extending from the sole to the true ankle joint as located by inserting the tip of the finger on the inside and at the front of the ankle joint and moving the foot up and down until the joint could be located and marked by a horizontal pen mark. This segment includes both feet and is designated as the foot or foot segment.

2. The calf, extending from the true ankle joint to the center of the knee joint as located on the inside of the knee by inserting the tip of the finger and moving the lower leg until the joint was located and marked. This segment includes both calves and is designated as the calf or calf segment.

3. The thigh, extending from the knee joint to the crotch as located by the crotch rod astride of which the subject stands while being measured. The crotch is approximately the same height as the great trochanter, but was chosen in preference to the latter because it is in the center line of the body and because it could be located with greater exactness. This segment includes both thighs and the lower part of the forearms and hands as they hang in a natural position at the side. This segment is designated as the thigh or thigh segment.

4. The leg, including the foot, calf and thigh. This is one of the three major segments of the body and is designated as the leg or total leg.

5. The loin, extending from the crotch to the center of the navel.

6. The abdomen, extending from the center of the navel to the center of the fifth intercostal space as located by inserting the tip of the finger into this space as near the sternum as possible and marking the center with a horizontal pen mark. This point was choosen as being more constant than the lower end of the sternum, since the latter is flexible and difficult to locate in young children and in many cases is entirely lacking.

7. The chest, extending from the center of the fifth intercostal space to the sternal crest or top of the sternum on the center line of the body.

8. The trunk, including the loin, abdomen and chest. This is the second major segment of the body and is designated as the trunk or total trunk. This segment and its three divisions include the portion of the arms alongside the segments as the subject stands in a natural upright position with the arms at the side.

9. The neck, extending from the sternal crest to the center of the auditory canal, and including the lower portion of the face.

10. The cranium, extending from the center of the auditory canal to the top of the head.

11. The head, including the neck and the cranium. This is the third major segment of the body and is designated as the head or total head.

12. The arms. These were not measured as a separate segment on account of their overlapping on the chest. However, the volume of the arms to the shoulder joint was measured after the other segments were completed.

MAKING THE MEASUREMENT

In making all measurements the tank was filled with water at body temperature and the room kept at a temperature of 80 F. A sheet of graph paper 16 by 21 inches (41 by 53 cm.) with five or ten divisions to the inch was adjusted to the graph board so that when the platform on which the subject stood had its upper surface exactly level with the surface of the water in the large tank when ready to overflow, the pens were directly over the zero line at the left and over their respective base lines. While the subject disrobed, the various items of information required on the data sheet were filled in. Then the following measurements were made and recorded on the data sheet: standing height, sitting height, weight and width and depth of the chest. The following division points were then located and marked with a short horizontal pen mark: ankle, knee, fifth intercostal space and sternal crest. The other division points were not marked, as the apparatus indicated the exact location of the crotch and the center of the navel; the center of the auditory canal and the top of the head were determined by sight.

The subject mounted to the platform and was instructed by the operator as follows:

1. Stand in the center of the platform in an easy and natural position, facing the front with the feet about 1 inch on either side of the little rod at the water level. The rod will drop down when your body rests on it.

2. You will be lowered to the ankle, knee, crotch, navel, bottom of sternum, top of sternum, auditory canal and top of the head. At each of these points the apparatus will be stopped long enough to allow the water to stop overflowing.

3. From the time the water reaches the abdomen, you will be lowered nearly to the division point, and when the water has almost stopped overflowing, the operator will say, "all right" or tap on the tank

if your head is under water. When the signal is given you must exhale as much as possible for about ten or fifteen seconds. You will then be raised slightly so that the apparatus will mark the division point. When you feel yourself being raised, you will know that you may breathe again. You may practice this breathing each time the apparatus is stopped before the abdomen is reached.

4. At the water level in front of you is a rubber tube through which you must breathe while your mouth and nose are under water. When you have been lowered to your chin, the tube will be placed in your mouth and a clamp put on your nose so that you may breathe without difficulty while your head in being measured. When under water try to breathe easily and naturally. The tube is provided with a whistle, which will sound if you breathe with too much force.

While the measurements were being made, the operator stood on a platform over the cumulative tank so that he could operate the lowering device and at the same time be in a position to look between the graph board and the top of the tank and see the division points as they neared the water level.

The subject was first lowered to the ankle and the overflow measured in one of the small tubes and then allowed to run into the cumulative tank so that the two measurements could be checked against each other. He was then raised slightly so that the point would be marked on the graph and then lowered to the knee. From this time on the water was allowed to pass through the tube directly into the cumulative tank. The next point indicated was the finger tips. Although this is not a division point between segments, it was indicated so that if a further study of the arms was desired, the length would be obtainable. All other division points were marked in the same way by raising the subject slightly after the water had stopped overflowing. Some subjects required much coaching to have them exhale fully as the water stopped overflowing while the segments affected by breathing were being measured.

After the sternal crest had been indicated at exhale, the subject inhaled fully, and the overflow was measured in one of the small tubes, indicating the lung capacity. The lung capacity obtained here was later added to the volume of the whole body at exhale to give the total volume at inhale. The water displaced while taking the lung capacity was returned to the large tank before proceeding with the measurements.

As the water approached the subject's chin, his nose was clamped with a small spring clamp and the breathing tube placed in his mouth. He was then allowed to practice breathing through the tube. When he was satisfied that the breathing could be performed properly, he

was lowered to the center of the auditory canal, which placed the mouth and nose under water but left the eyes above the surface. After this point had been properly recorded, the subject was raised so that he could remove the tube and breathe naturally again. When he was ready to make the final descent, he was cautioned to stand with his feet firmly on the bottom and exhale completely when the operator tapped on the tank. He was further instructed that when the water had stopped overflowing the operator would tap on the tank a second time, when he should inhale fully. This gave the lung capacity a second time and the displacement of the total body at full inhale. The subject was then raised and the tank refilled. With the subject standing on the ladder outside the tank, the displacement of each arm was taken by submerging the arm to the center of the shoulder joint as located on the top of the shoulder.

Measurements had to be repeated on three subjects because of improper breathing or failure to exhale fully at the division points affected by breathing. Two measurements had to be discarded because the subjects failed to learn how to breathe properly while under water. Two boys failed to take the test after appearing for examination on account of being afraid of being submerged. Seven other boys failed to take the test on account of colds or other illness.

PRESENTATION OF MATERIAL

All data and detailed measurements on which this study is based are presented in the appendix. The data on each subject are in a horizontal line across the table, while all the data on any one item are in a vertical column. The subjects are grouped by ages from 5 to 19, and below each age group and each subgroup are given the means of the distribution. From these means, tables (tables 17 to 48) were constructed for each item and for each group. From these tables, table 1, presenting age norms for the whole body and each of its segments, was derived. On account of the inadequate number of cases at each end of the distribution, these age norms were smoothed and the results presented in table 2. This table presents the tentative growth norms for the whole body and its segments. Tables 3 and 4 present this same material in percentage of total body volume to show the relative size of the various segments. Tables 5 and 6 present the same material in percentage of increase in volume over the volume of the preceding year to show the relative rate of growth from year to year. Tables 7 to 16 present the data for the university group and the settlement group in the same way as tables 1 to 6 present the data for both groups combined.

Part III presents the growth of the body as a whole, while parts IV to VI present the growth of the three major segments and their minor segments.

Part VII gives the summary, including the findings and significance of the study together with a discussion of its limitations and possible improvements and extension of the method and technic used.

TABLE 1.—*Mean Volume of Body and Segments (at Exhale) of One Hundred and Sixty-Four Boys Measured by Water Displacement*

	Segment												
Age	Cranium	Neck	Head	Chest	Abdomen	Loin	Trunk	Thigh	Calf	Foot	Leg	Body	Cases
	Cubic Inches												
5	150	60	210	165	240	200	625	299	110	21	430	1,265	1
6	150	80	230	135	145	210	490	320	145	35	500	1,220	2
7	160	90	250	230	240	200	670	448	130	42	620	1,540	1
8	140	70	210	200	290	270	760	404	140	46	590	1,560	1
9	162	95	257	293	272	223	788	418	168	52	638	1,683	3
10	159	112	271	296	337	334	967	444	172	54	670	1,908	6
11	155	108	263	295	330	284	909	453	174	58	685	1,857	10
12	161	130	291	412	393	335	1,139	605	209	65	879	2,309	17
13	167	126	293	407	405	346	1,159	606	223	72	901	2,353	27
14	166	150	316	482	454	418	1,357	719	260	76	1,056	2,729	32
15	170	147	317	554	482	463	1,499	800	270	81	1,151	2,967	37
16	173	161	334	624	580	535	1,759	886	314	95	1,295	3,389	17
17	176	171	347	690	576	581	1,847	973	333	98	1,403	3,597	8
18	190	210	400	690	740	690	2,120	1,080	315	85	1,480	4,000	1
19	180	240	420	580	540	620	1,740	790	280	70	1,140	3,300	1
	Cubic Centimeters												
5	2,457	983	3,440	3,030	3,930	3,275	10,235	4,896	1,801	344	7,041	20,716	1
6	2,457	1,310	3,767	2,211	2,375	3,439	8,025	5,241	2,375	573	8,189	19,981	2
7	2,620	1,474	4,094	3,767	3,930	3,275	10,972	7,336	2,129	688	10,154	25,221	1
8	2,293	1,146	3,449	3,275	4,749	4,422	12,447	6,617	2,293	753	9,663	25,549	1
9	2,653	1,556	4,209	4,798	4,454	3,652	12,904	6,845	2,751	852	10,448	27,561	2
10	2,604	1,834	4,438	4,847	5,518	5,469	15,836	7,271	2,817	884	10,973	31,247	6
11	2,538	1,767	4,307	4,831	5,404	4,651	14,887	7,410	2,850	950	11,210	30,404	10
12	2,637	2,129	4,766	6,747	6,436	5,486	18,669	9,908	3,422	1,065	14,395	37,830	17
13	2,735	2,064	4,799	6,666	6,633	5,666	18,965	9,924	3,652	1,179	14,755	38,519	27
14	2,719	2,457	5,176	7,893	7,420	6,845	22,158	11,775	4,258	1,245	17,278	44,612	32
15	2,784	2,407	5,191	9,073	7,894	7,585	24,552	13,102	4,422	1,327	18,851	48,594	37
16	2,833	2,637	5,470	10,219	9,499	9,089	28,807	15,511	5,142	1,556	22,209	56,486	17
17	2,882	2,800	5,683	11,300	9,434	9,515	30,249	15,936	5,453	1,605	22,994	58,926	8
18	3,112	3,439	6,551	11,300	12,119	11,300	34,710	17,687	5,158	1,392	24,238	65,510	1
19	2,948	3,930	6,878	9,499	8,844	10,154	38,497	12,938	4,586	1,146	18,670	54,045	1

III. THE BODY AS A WHOLE

The purpose of this section is to present the growth of the whole body in terms of volume. Certain other problems closely related to the main purpose of the section are also discussed: validity of formulas for body volume, specific gravity of the body and the maximum length of the body.

A REPRESENTATIVE GROUP

Although the group measured was an unselected group, there are certain limitations that might lead one to believe that only the stronger and larger subjects in each age group were measured. For instance, in the university group only the boys for whom the permission of the parents could be secured were measured. It might be presumed

TABLE 2.—*Mean Volume of Body and Segments as Derived from Smoothing the Growth Curves*

Age	Segment: Cranium	Neck	Head	Chest	Abdomen	Loin	Trunk	Thigh	Calf	Foot	Leg	Body	Cases
						Cubic Inches							
5	147	63	210	150	162	198	610	285	125	30	440	1,160	1
6	155	80	235	175	191	204	570	350	130	35	515	1,320	2
7	159	91	250	220	231	209	660	365	135	40	580	1,470	1
8	162	98	260	230	256	232	720	429	141	45	615	1,595	1
9	163	102	265	280	280	260	820	432	153	50	635	1,720	3
10	164	106	270	310	310	285	905	448	167	55	670	1,845	6
11	157	118	285	330	337	308	975	485	189	61	735	1,995	10
12	169	141	310	360	372	328	1,080	562	212	66	840	2,210	17
13	172	158	330	400	407	363	1,170	637	232	71	940	2,440	27
14	176	169	345	460	445	410	1,315	710	254	76	1,040	2,700	32
-15	178	182	360	530	498	472	1,500	805	274	81	1,160	3,020	37
-16	179	191	370	600	555	535	1,690	900	294	86	1,880	3,340	17
17	179	201	380	630	630	600	1,860	967	304	89	1,360	3,609	8
-18	180	215	395	635	650	640	1,925	1,005	305	90	1,400	3,720	1
-19	180	220	400	640	655	665	1,960	1,025	305	90	1,420	3,780	1
						Cubic Centimeters							
5	2,407	1,032	3,439	2,457	2,653	3,242	8,352	4,667	2,047	491	7,205	18,996	1
6	2,538	1,310	3,848	2,866	3,128	3,340	9,334	5,732	2,129	573	8,434	21,616	2
7	2,604	1,490	4,094	3,603	3,783	3,422	10,808	6,304	2,211	655	9,170	24,072	1
8	2,653	1,605	4,258	3,767	4,225	3,800	11,792	7,025	2,309	736	10,070	26,120	1
9	2,669	1,670	4,339	4,586	4,586	4,258	13,430	7,074	2,506	819	10,399	28,168	3
10	2,686	1,736	4,422	5,077	5,077	4,667	14,821	7,336	2,735	901	10,972	30,215	6
11	2,735	1,932	4,667	5,404	5,518	5,044	15,966	7,943	3,095	999	12,037	32,670	10
12	2,768	2,309	5,077	5,896	6,092	5,371	17,359	9,204	3,471	1,081	13,756	36,190	17
13	2,817	2,588	5,405	6,551	6,666	5,945	19,162	10,433	3,800	1,163	15,396	39,963	27
14	2,882	2,768	5,650	7,533	7,287	6,715	21,535	11,628	4,160	1,245	17,033	44,218	32
15	2,915	2,981	5,896	8,680	8,156	7,730	24,566	13,184	4,487	1,327	18,998	49,460	37
16	2,931	3,128	6,059	9,826	9,089	8,762	27,677	14,739	4,815	1,408	20,962	54,698	17
17	2,931	3,291	6,222	10,318	10,318	9,826	30,462	15,837	4,980	1,458	22,275	58,959	8
18	2,948	3,520	6,468	10,350	10,645	10,481	31,476	16,459	4,996	1,474	22,929	60,873	1
19	2,948	3,603	6,551	10,481	10,727	10,891	32,099	16,787	4,996	1,474	23,257	61,907	1

TABLE 3.—*Mean Volume of Body and Segments in Percentage of Total Body Volume*

Age	Segment: Cranium	Neck	Head	Chest	Abdomen	Loin	Trunk	Thigh	Calf	Foot	Leg	Cases
5.....	11.9	4.7	16.6	14.5	19.0	15.8	49.4	23.6	8.7	1.7	34.0	1
6.....	12.3	6.5	18.9	11.1	11.9	17.2	40.2	26.2	11.9	2.9	41.0	2
7.....	10.4	5.8	16.2	14.9	15.6	13.0	43.5	29.1	8.4	2.7	40.3	1
8.....	9.0	4.5	13.5	12.8	18.6	17.3	48.7	25.9	9.0	2.9	37.8	1
9.....	9.6	5.6	15.3	17.4	16.2	13.3	46.8	24.8	10.0	3.1	37.9	3
10.....	8.3	6.9	14.2	15.5	17.7	17.5	50.7	23.3	9.0	2.8	35.1	6
11.....	8.3	5.8	14.2	15.9	17.8	15.3	48.9	24.4	9.4	3.1	36.9	10
12.....	7.0	5.6	12.6	17.8	17.0	14.5	49.3	26.2	9.1	2.8	38.1	17
13.....	7.1	5.4	12.5	17.3	17.2	14.7	49.3	25.8	9.5	3.1	38.3	27
14.....	6.1	5.5	11.6	17.7	16.6	15.3	49.7	26.3	9.5	2.8	38.7	32
15.....	5.7	5.0	10.7	18.7	16.2	15.6	50.5	27.0	9.1	2.7	38.8	37
16.....	5.1	4.8	9.9	18.4	17.1	16.4	51.9	26.1	9.3	2.8	38.2	17
17.....	4.9	4.8	9.6	19.2	18.0	16.2	51.3	27.1	9.3	2.7	39.0	8
18.....	4.8	5.3	10.0	17.3	18.5	17.3	53.0	27.0	7.9	2.1	37.0	1
19.....	5.5	7.3	12.7	17.6	16.4	18.8	52.7	25.9	8.5	2.1	34.5	1

TABLE 4.—*Mean Volume of Body and Segments in Percentage of Total Body Volume Derived From Smoothing the Growth Curves*

Age	Segment: Cranium	Neck	Head	Chest	Abdomen	Loin	Trunk	Thigh	Calf	Foot	Leg
5.....	12.7	5.4	18.1	12.9	14.0	17.1	44.0	24.5	10.8	2.6	37.9
6.....	11.7	6.1	17.8	13.3	14.4	15.5	45.8	26.5	9.8	2.7	39.0
7.....	10.8	6.2	17.0	15.0	15.7	14.2	44.9	26.2	9.2	2.7	38.1
8.....	10.2	6.1	16.3	14.4	16.2	14.5	45.1	26.9	8.8	2.8	38.6
9.....	9.5	5.9	15.4	16.3	16.3	15.1	47.7	25.1	8.9	2.9	36.9
10.....	8.9	5.7	14.6	16.8	16.8	15.4	49.0	24.4	9.0	3.0	36.4
11.....	8.4	5.9	14.3	16.5	16.9	15.4	48.9	24.3	9.5	3.0	36.8
12.....	7.6	6.4	14.0	16.3	16.8	14.8	48.0	25.4	9.6	3.0	38.0
13.....	7.0	6.5	13.5	16.4	16.7	14.9	48.0	26.1	9.5	2.9	38.5
14.....	6.5	6.3	12.8	17.0	16.5	15.2	48.7	26.3	9.4	2.8	38.5
15.....	5.9	6.0	11.9	17.6	16.5	15.6	49.7	26.6	9.1	2.7	38.4
16.....	5.4	5.7	11.1	18.0	18.6	16.0	50.6	26.9	8.8	2.6	38.3
17.....	5.0	5.6	10.6	17.5	17.5	15.7	51.7	26.9	8.4	2.5	37.8
18.....	4.8	5.8	10.6	17.1	17.5	17.2	51.7	27.0	8.2	2.4	37.6
19.....	4.8	5.8	10.6	16.9	17.3	17.6	51.8	27.1	8.1	2.4	37.6

that if a boy was small or weak for his age the parents would not give permission. With the settlement group it was possible to secure subjects only by taking "gangs" as organized by the boys themselves. It might also be presumed that the "gang" rejects the small or weak boys.

How near the groups measured by water displacement are average or representative groups for their age can best be answered by comparing them with some reliable standard of physical growth. Table 17 and the tables immediately following give the mean age, sitting height, standing height, weight and width and depth of the chest for all groups included in this study. Since the correlation between volume and weight is much higher than the correlation between volume and any of the other measurements, it is believed that a comparison of the groups with the weight standards will best show the relation. In figure 3, the mean weight of these groups is compared to Baldwin's weight norm

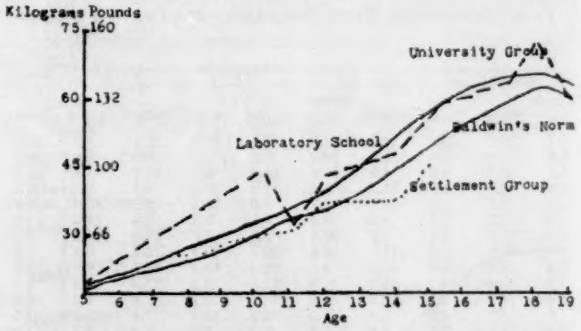

Fig. 3.—Weight of groups measured by water displacement and other weight norms.

(p. 152) and the weight norm established by me from 1,500 birthday measurements of Laboratory School boys.

Since there are only two cases (one at 5 and one at 10 years) below 11 years and two cases (one at 18 and one at 19 years) in the university group, its weight norm is very close to the norm for the Laboratory Schools and therefore could be said to be representative of the group from which the university group was taken. The settlement group is much lower than the university group at all points. For the ages from 7 to 9 and 12, the settlement group is above Baldwin's norm, and possibly for the lower ages the larger subjects were measured, but from 13 years of age and above there appears to be no tendency to select the larger subjects.

VOLUME OF THE WHOLE BODY

The volume of all subjects was taken at full inhale and at full exhale. The volume of the segments was taken at exhale only because

TABLE 5.—*Increase of Body and Segments in Percentage of Volume the Preceding Year*

	Segment												
Age	Cranium	Neck	Head	Chest	Abdomen	Loin	Trunk	Thigh	Calf	Foot	Leg	Body	Cases
6	0	33.3	9.5	−27.0	−39.8	5.0	−21.6	7.0	31.8	66.7	13.3	−3.6	2
7	6.7	12.5	8.7	70.4	65.5	−4.8	36.7	38.7	−10.3	20.0	24.0	26.2	1
8	−12.5	−22.2	−16.0	−13.0	24.2	35.0	13.4	−9.8	7.7	9.5	−4.8	1.3	1
9	15.7	35.7	22.4	48.5	−6.2	−17.4	3.7	3.5	20.0	13.0	8.1	7.9	3
10	−2.3	7.4	5.4	1.0	23.9	49.8	10.0	6.2	2.4	3.8	5.0	13.4	6
11	−2.5	−3.5	−3.0	−0.3	−2.1	−15.0	−6.0	2.0	1.2	7.4	2.2	−2.7	10
12	3.9	20.4	10.6	39.7	19.1	18.0	25.3	33.6	20.1	12.1	28.3	24.3	17
13	3.7	−3.1	0.7	−1.8	3.1	2.7	1.8	0.2	6.7	13.5	2.5	1.9	27
14	−0.6	19.0	7.8	18.4	12.1	20.8	17.1	16.1	16.6	5.6	17.2	16.0	32
15	2.4	−2.0	0.3	14.9	6.2	10.8	10.5	11.3	3.8	6.6	9.0	8.7	37
16	1.8	9.5	5.4	12.6	20.3	19.9	17.3	10.8	16.3	17.3	12.5	14.2	17
17	1.7	6.2	3.9	10.0	0.7	4.7	5.0	9.8	6.1	3.2	8.3	6.1	8
18	6.0	22.8	15.3	0	28.5	18.6	14.8	11.0	−5.4	−13.2	5.5	11.2	1
19	−5.3	14.2	5.0	−15.9	−27.0	−10.1	−17.9	−26.9	−11.1	−17.6	−23.0	−17.5	1

TABLE 6.—*Increase of Body and Segments in Percentage of Volume the Preceding Year Determined From Smoothing the Growth Curves*

	Segment											
Age	Cranium	Neck	Head	Chest	Abdomen	Loin	Trunk	Thigh	Calf	Foot	Leg	Body
6.....	5.4	20.7	11.9	16.7	17.9	3.0	11.8	22.8	4.0	16.7	17.0	13.8
7.....	2.6	13.8	6.4	25.7	20.9	2.5	15.8	10.0	3.8	14.3	8.7	11.4
8.....	1.9	7.7	4.0	4.5	11.6	11.0	9.1	11.4	4.4	12.5	9.8	6.5
9.....	0.6	4.1	1.9	21.7	8.5	12.1	13.9	0.7	8.5	11.1	3.3	7.6
10.....	0.6	3.9	1.9	10.7	10.7	9.6	10.4	3.7	9.2	10.0	5.5	7.3
11.....	1.8	11.3	5.6	6.5	8.7	8.1	7.7	8.3	13.3	10.9	9.7	8.1
12.....	1.2	10.5	8.8	9.1	10.4	6.5	8.7	15.9	12.2	8.2	14.3	10.8
13.....	1.8	12.1	6.5	11.1	9.4	10.7	10.4	13.3	9.4	7.6	11.9	10.4
14.....	2.3	7.0	4.5	15.0	9.3	12.9	12.4	11.5	9.5	7.0	10.6	10.7
15.....	1.1	7.7	4.3	15.3	11.9	15.1	14.1	13.4	7.9	6.6	11.5	11.9
16.....	0.6	4.9	2.8	13.2	11.4	13.3	12.7	11.8	7.3	6.2	10.3	10.6
17.....	0	5.2	4.0	5.0	15.3	12.1	10.7	7.4	3.4	3.5	6.3	7.8
18.....	0.6	7.0	2.6	0.8	3.1	6.7	3.5	3.9	0.3	1.1	2.9	3.3
19.....	0	2.3	1.3	9.8	0.8	3.9	1.6	2.0	0	0	1.4	1.6

TABLE 7.—*Settlement Group: Mean Volume of the Body and the Segments*

	Segment											
Age	Cranium	Neck	Head	Chest	Abdomen	Loin	Trunk	Thigh	Calf	Foot	Leg	Body	Cases
						Cubic Inches							
6	150	80	230	135	145	210	490	320	145	35	500	1,220	2
7	160	90	250	230	240	200	670	448	130	42	620	1,540	1
8	140	70	210	200	290	270	760	404	140	46	590	1,560	1
9	162	95	257	293	272	226	788	418	168	52	638	1,083	3
10	158	105	263	269	325	283	877	416	168	51	634	1,778	5
11	159	108	267	286	329	283	696	445	171	60	677	1,840	8
12	167	114	281	409	389	304	1,101	554	204	61	820	2,202	7
13	165	116	281	376	359	292	1,028	582	211	70	821	2,137	14
14	171	132	304	461	427	354	1,252	652	222	71	947	2,502	10
15	170	139	308	515	430	389	1,338	739	236	77	1,051	2,697	18
						Cubic Centimeters							
6	2,457	1,310	3,767	2,211	2,375	3,439	8,025	5,241	2,375	573	8,189	19,980	2
7	2,620	1,474	4,094	3,767	3,930	3,275	10,972	7,336	2,129	688	10,153	25,221	1
8	2,293	1,146	3,439	3,275	4,749	4,422	12,466	6,617	2,293	753	9,663	25,548	1
9	2,653	1,556	4,209	4,798	4,454	3,652	12,904	6,845	2,751	852	10,448	27,562	3
10	2,588	1,720	4,308	4,405	5,322	4,635	14,362	6,813	2,719	835	10,367	29,118	5
11	2,604	1,769	4,373	4,684	5,388	4,635	14,707	7,287	2,800	983	11,070	30,134	8
12	2,735	1,867	4,602	6,698	6,370	4,980	1.,048	9,073	3,340	999	13,412	36,063	7
13	2,702	1,900	4,602	6,157	5,879	4,782	16,818	9,532	3,455	1,146	14,133	34,995	14
14	2,800	2,162	4,962	7,550	6,992	5,797	20,339	10,678	3,636	1,163	15,477	40,973	10
15	2,784	2,276	5,060	8,434	7,042	6,370	21,846	12,102	3,865	1,261	17,228	44,165	18

some of the segments are not affected by inhaling, and therefore the volume of the various segments would be more comparable at exhale.

Figure 4 compares the university and settlement groups as to total body volume at inhale and at exhale. This figure is constructed from the data presented in table 20. The settlement group at inhale rarely reached the university group at exhale.

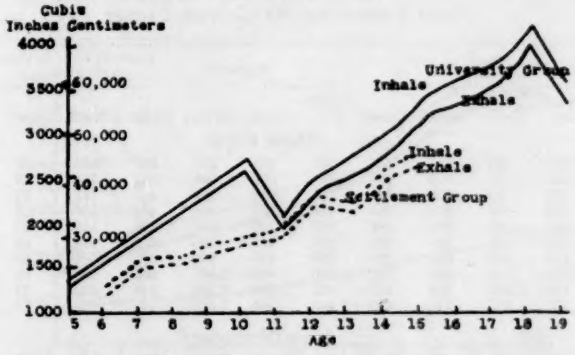

Fig. 4.—Volume of the total body at inhale and at exhale.

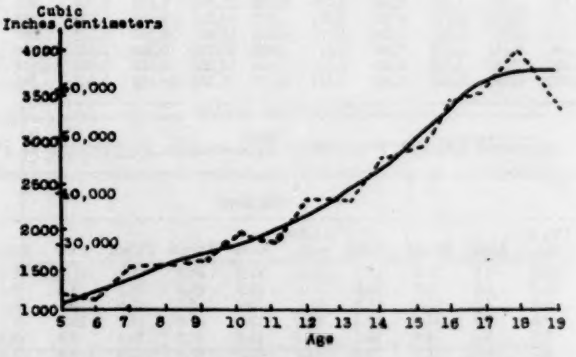

Fig. 5.—Original and smoothed growth curve for total body volume. The broken line indicates the original growth curve; the continuous line, the smoothed growth curve.

The mean volume of the whole body and the various segments is presented in table 1, when both groups are combined. When the growth curve for the whole body was plotted, as indicated by the dotted line in figure 5, it appeared to be very irregular. This is probably due to the small number of cases in each age group. This growth curve was smoothed, as indicated by the solid line in figure 5, as it is believed that the smooth curve more nearly represents the true growth curve than does the very irregular curve given by plotting the means of each age group.

Tentative Growth Norms.—The values derived from smoothing the growth curves for the whole body and for each of the segments are presented in table 2 as the tentative growth norms derived from this study. This smooth curve for body volume is similar to the curve for weight presented in figure 3. The curve for volume rises more

TABLE 8.—*Settlement Group: Volume of the Body and the Segments as Derived From Smoothing the Growth Curves*

Age	Segment											
	Cranium	Neck	Head	Chest	Abdomen	Loin	Trunk	Thigh	Calf	Foot	Leg	Body
	Cubic Inches											
6.....	153	80	235	175	191	204	570	350	130	35	515	1,320
7.....	159	91	250	220	231	209	660	385	135	40	560	1,470
8.....	162	98	260	230	258	232	720	429	141	45	615	1,596
9.....	163	102	265	260	280	230	820	432	158	50	635	1,720
10.....	165	104	269	281	290	230	831	435	165	55	655	1,755
11.....	167	123	290	285	330	255	900	452	178	60	690	1,880
12.....	170	136	306	324	355	300	979	500	190	65	755	2,040
13.....	171	149	320	390	390	305	1,065	566	200	69	835	2,240
14.....	173	155	328	427	425	330	1,182	642	220	73	945	2,455
15.....	175	165	340	470	446	400	1,315	742	236	77	1,055	2,710
	Cubic Centimeters											
6.....	2,538	1,310	3,848	2,866	3,128	3,340	9,334	5,732	2,129	573	8,434	21,618
7.....	2,604	1,490	4,094	3,603	3,783	3,422	10,808	6,304	2,211	655	9,170	24,074
8.....	2,653	1,605	4,258	3,767	4,225	3,800	11,792	7,025	2,309	736	10,070	26,121
9.....	2,669	1,670	4,339	4,586	4,586	4,258	13,430	7,074	2,506	819	10,399	28,168
10.....	2,702	1,703	4,405	4,602	4,749	4,258	13,609	7,123	2,702	901	10,726	28,742
11.....	2,735	2,014	4,749	4,667	5,404	4,667	14,738	7,402	2,915	983	11,300	30,790
12.....	2,784	2,227	5,011	5,306	5,713	4,913	15,982	8,189	3,112	1,065	12,366	33,400
13.....	2,800	2,440	5,240	6,387	6,387	4,996	17,770	9,269	3,275	1,130	13,674	36,680
14.....	2,833	2,505	5,338	6,992	6,959	5,404	19,355	10,678	3,606	1,196	15,477	40,202
15.....	2,866	2,702	5,568	7,697	7,287	6,551	21,535	12,152	3,865	1,261	17,278	44,380

TABLE 9.—*Settlement Group: Volume of Segments in Percentage of Total Volume*

Age	Segment											
	Cranium	Neck	Head	Chest	Abdomen	Loin	Trunk	Thigh	Calf	Foot	Leg	Cases
6.....	12.3	6.6	18.9	11.1	11.9	17.2	40.2	26.2	11.9	2.9	41.0	2
7.....	10.4	5.8	16.2	14.9	15.6	13.0	43.5	29.1	8.4	2.7	40.3	1
8.....	9.0	4.5	13.5	12.8	18.6	17.3	45.7	25.9	9.0	2.9	37.8	1
9.....	9.6	5.6	15.3	17.4	16.2	13.3	46.8	24.8	10.0	3.1	37.9	3
10.....	8.9	5.9	14.8	15.1	18.4	15.9	49.3	23.4	9.3	2.9	35.6	5
11.....	8.7	5.8	14.6	15.4	17.8	15.5	48.6	22.4	9.4	3.3	36.9	8
12.....	7.7	5.3	13.0	18.4	17.7	11.4	49.9	25.2	9.2	2.8	37.2	7
13.....	7.8	5.4	13.2	17.6	16.7	13.7	48.0	25.6	9.9	3.3	38.8	14
14.....	7.0	5.3	12.3	18.1	17.1	14.3	49.9	26.0	8.9	2.9	37.8	10
15.....	6.4	5.2	11.5	18.8	16.0	14.7	49.5	27.3	8.8	2.9	39.0	18

rapidly at the upper end than does the weight curve, which is probably due to the unusual size of the one case at 18. The growth curve derived from volume is so similar to the growth curve derived from weight that if one were to consider only the growth of the whole body, nothing would be gained by the new method of measurement. It is when one is able to show the volume or size of the parts of the body and their relative proportions and rate of growth that the unique possibilities of the method is brought out.

Relation of Major Segments to the Whole Body.—Figure 6 presents the relation of the head, trunk and legs to the body as a whole in terms of volume. The data for this figure are also taken from table 1. This relation could not be presented in a consistent unit until now. The relation has been shown by using length, but since it is only one of the three dimensions it is not a proper unit to show the relation of volumes. The head and neck are more than half as long as the trunk,

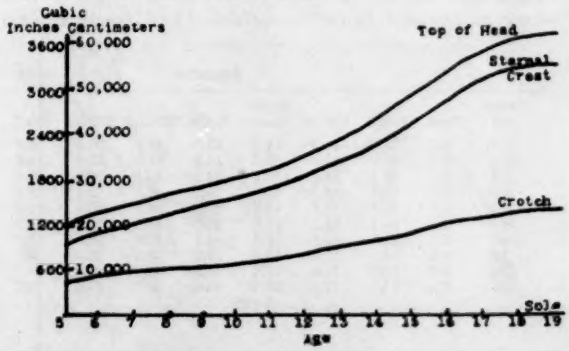

Fig. 6.—Relation of the volume of the three major segments to the volume of the total body.

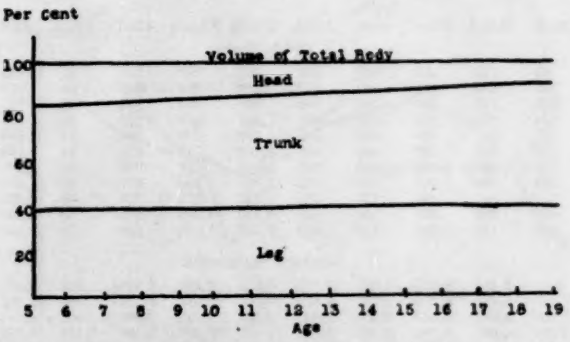

Fig. 7.—Three major segments in percentage of total volume.

but, as may be seen from the graph, they are less than one-fifth in volume at most ages.

In figure 7 is shown the relation of the volume of the whole body and the three major segments in percentage of total body volume. The values for this figure are taken from table 4, in which the mean volume of each segment at each age is reduced to percentage of total volume. It is seen that from 5 to 19 years of age the leg is almost constant around 39 per cent of the total volume. The head decreases from 18 per cent to 10 per cent, while the trunk increases from about 44 per

cent to 52 per cent. It is interesting to note that when the growth of segments is given in terms of length, the leg is about 50 per cent and the trunk about 30 per cent, and the length of the trunk maintains a uniform relation to the length of the whole body while the leg increases more in proportion. In other words, in changing from length to volume, the relation of the leg and trunk is almost completely reversed.

TABLE 10.—*Settlement Group: Volume of Segments in Percentage of Total Volume as Derived From Smoothing The Growth Curves*

	Segment										
Age	Cranium	Neck	Head	Chest	Abdomen	Loin	Trunk	Thigh	Calf	Foot	Leg
6	11.7	6.1	17.8	13.3	14.4	15.5	43.2	26.5	9.8	2.7	39.0
7	10.8	6.2	17.0	15.0	15.7	14.2	44.9	26.2	9.2	2.7	38.1
8	10.2	6.1	16.3	14.4	16.2	14.5	45.1	26.9	8.8	2.8	38.6
9	9.5	6.9	15.4	16.3	16.3	15.1	47.7	25.1	8.9	2.9	36.9
10	9.4	6.9	15.4	16.8	16.8	15.1	48.7	25.1	8.9	2.9	38.9
11	8.9	6.5	15.4	15.2	17.6	15.2	48.0	24.0	9.5	3.2	36.7
12	8.3	6.7	15.0	15.8	17.4	14.7	47.9	24.5	9.3	3.2	37.0
13	7.7	6.6	14.3	17.4	17.4	13.9	48.5	25.3	9.3	3.1	37.7
14	7.0	6.3	13.3	17.4	17.3	13.5	48.2	26.5	9.0	3.0	38.5
15	6.5	6.1	12.5	17.3	16.4	14.8	48.5	27.3	8.7	2.8	38.8

TABLE 11.—*University Group: Mean Volume of the Body and the Segments*

	Segment											
Age	Cranium	Neck	Head	Chest	Abdomen	Loin	Trunk	Thigh	Calf	Foot	Leg	Body	Cases
						Cubic Inches							
5	150	60	210	155	240	200	625	299	110	21	430	1,265	1
10	160	150	310	410	400	590	1,400	585	200	65	850	2,560	1
11	140	108	248	330	330	290	590	485	188	52	725	1,923	2
12	158	141	298	414	396	357	1,167	641	219	68	920	2,385	10
13	168	137	305	440	454	482	1,300	670	236	74	980	2,556	13
14	164	159	322	491	466	447	1,404	749	278	78	1,108	2,833	22
15	170	156	326	590	532	530	1,552	858	299	87	1,245	3,222	19
16	173	161	334	624	580	555	1,759	886	314	95	1,295	3,389	17
17	171	177	347	690	576	581	1,847	973	333	98	1,406	3,597	8
18	190	210	400	690	740	690	2,120	1,090	315	85	1,480	4,000	1
19	180	240	420	580	540	620	1,740	790	280	70	1,140	3,300	1
						Cubic Centimeters							
5	2,457	983	3,440	3,030	3,930	3,275	10,235	4,896	1,801	344	7,041	20,716	1
10	2,620	2,457	5,077	6,715	6,551	9,662	22,928	9,581	3,275	1,066	13,922	51,920	1
11	2,293	1,769	4,062	5,404	5,404	4,749	15,557	7,943	3,079	852	11,874	31,489	2
12	2,588	2,309	4,897	6,780	6,485	5,746	19,011	10,497	3,586	1,114	15,197	39,062	10
13	2,751	2,244	4,995	7,206	7,426	7,894	22,526	10,973	3,865	1,212	16,050	41,842	13
14	2,686	2,604	5,290	8,041	7,631	7,321	22,993	12,266	4,552	1,277	18,095	46,390	22
15	2,784	2,555	5,339	9,662	8,713	8,680	27,055	14,051	4,896	1,425	20,372	52,763	19
16	2,833	2,537	5,470	10,219	9,499	9,089	28,807	15,511	5,142	1,556	22,209	56,486	17
17	2,882	2,800	5,683	11,300	9,434	9,515	30,249	15,986	5,453	1,605	22,994	58,926	8
18	3,112	3,439	6,551	11,300	12,119	11,300	34,710	17,687	5,158	1,392	24,238	65,510	1
19	2,948	3,930	6,878	9,499	8,844	10,154	28,497	12,938	4,586	1,146	18,670	54,045	1

In order to show the relative rate at which the body and the various segments grow at different ages, tables 5 and 6 were constructed. In these tables the increase in volume between any two years is converted into percentage of the volume at the beginning of the year period. For example, the total body volume (table 2) at 5 years is 1,160 cubic inches, while at 6 years it is 1,320 cubic inches, an increase of 160

cubic inches. This increase is equal to 13.8 per cent of 1,160 cubic inches, the volume at 5 years.

The Growth Lag and the Adolescent Spurt.—Figure 8 presents the relative rate of growth for the whole body and the three major segments based on all measurements made by water displacement. Figure 9 presents the relative rate of growth for the settlement group and the university group for the whole body. It is believed that the evi-

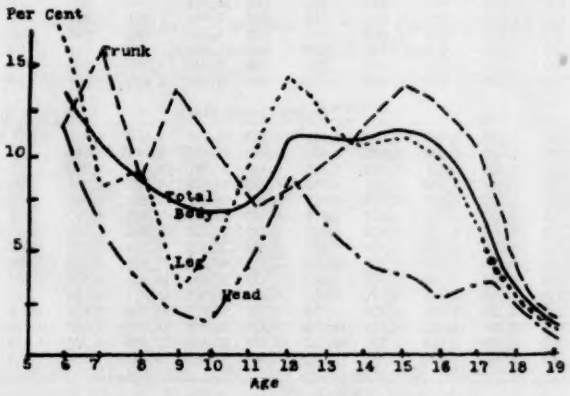

Fig. 8.—Relative rate of growth of the total body and the three major segments.

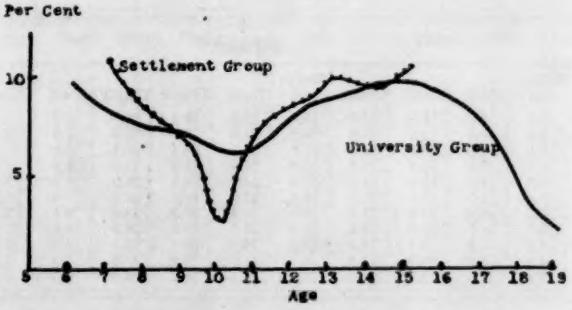

Fig. 9.—Relative rate of growth on the total body in the two groups studied.

dence presented in these figures can throw much light on the question as to whether there is a slowing down in growth followed by an adolescent spurt. Dr. Franzen stated: "The male lag comes between 10½ and 12½ years of age" (p. 192). Bigelow, basing his conclusions on the height and weight tables of Baldwin stated: "There is on the average no year of surprising growth" (p. 27). Figure 8 seems to indicate that the whole body grows relatively faster between 5 and 6 years than it does at any subsequent time. This rate of growth declines to 10 years of age and then rises suddenly and remains high until after 16, when it drops rapidly and is very slight at 19. It appears

TABLE 12.—*University Group: Volume of the Body and the Segments as Derived From Smoothing the Growth Curves*

Age	Segment											
	Cranium	Neck	Head	Chest	Abdomen	Loin	Trunk	Thigh	Calf	Foot	Leg	Body
	Cubic Inches											
5	150	70	220	230	270	240	740	300	110	30	440	1,400
6	158	85	243	237	285	265	787	350	125	53	510	1,540
7	162	96	258	247	300	290	837	390	140	40	570	1,665
8	165	103	268	277	305	305	887	430	155	46	630	1,785
9	166	107	273	312	310	330	952	480	165	30	695	1,920
10	167	109	276	340	330	345	1,035	485	185	58	725	2,040
11	170	128	298	377	345	350	1,072	550	198	62	810	2,180
12	173	142	315	413	390	360	1,165	595	218	67	880	2,360
13	174	160	334	441	425	380	1,246	655	242	73	1,000	2,580
14	176	170	346	484	465	435	1,384	755	266	79	1,100	2,630
15	178	184	362	558	510	495	1,563	825	286	84	1,195	3,110
16	179	191	370	600	555	535	1,690	900	294	86	1,280	3,340
17	179	201	360	630	630	600	1,860	967	304	89	1,360	3,600
18	180	215	395	635	650	640	1,925	1,005	305	90	1,400	3,720
19	180	220	400	640	855	665	1,960	1,025	305	90	1,420	3,780
	Cubic Centimeters											
5	2,457	1,146	3,603	3,767	4,422	3,930	12,119	4,913	1,801	491	7,206	22,929
6	2,588	1,392	3,980	3,881	4,667	4,339	12,887	5,732	2,047	573	8,352	25,221
7	2,653	1,572	4,225	4,045	5,913	4,749	13,707	6,387	2,293	655	9,335	27,268
8	2,702	1,687	4,389	4,536	4,996	4,996	14,528	7,042	2,538	736	10,316	29,233
9	2,719	1,752	4,471	5,109	5,077	5,404	15,590	7,861	2,702	819	11,382	31,443
10	2,735	1,785	4,520	5,715	5,404	5,650	16,769	7,943	3,030	901	11,874	33,403
11	2,784	2,096	4,880	6,173	5,650	5,732	17,555	9,007	3,242	1,015	13,264	35,699
12	2,833	2,326	5,159	6,796	6,387	5,896	19,079	9,744	3,520	1,097	14,361	38,650
13	2,850	2,620	5,470	7,222	6,959	6,223	20,404	11,218	3,963	1,196	16,377	42,251
14	2,882	2,784	5,666	7,927	7,615	7,123	22,665	12,365	4,356	1,294	18,015	46,350
15	2,915	3,013	5,928	9,138	8,352	8,107	25,597	13,511	4,684	1,376	19,571	50,936
16	2,931	3,128	6,059	9,826	9,089	8,762	27,677	14,739	4,815	1,408	20,962	54,698
17	2,931	3,291	6,222	10,318	10,318	9,826	30,462	15,837	4,980	1,458	22,275	58,959
18	2,948	3,520	6,468	10,350	10,645	10,481	31,476	16,459	4,996	1,474	22,929	60,873
19	2,948	3,603	6,551	10,481	10,727	10,891	92,099	16,787	4,996	1,474	23,257	61,907

TABLE 13.—*University Group: Volume of the Segments in Percentage of Total Volume*

Age	Segment											Cases
	Cranium	Neck	Head	Chest	Abdomen	Loin	Trunk	Thigh	Calf	Foot	Leg	
5	11.9	4.7	16.6	14.6	19.0	15.8	49.4	23.6	8.7	1.7	34.0	1
10	6.3	5.9	12.1	16.0	15.6	23.0	54.7	22.9	7.8	2.5	33.2	1
11	7.3	6.5	12.9	17.1	17.1	15.1	49.4	25.2	9.8	2.7	37.8	2
12	6.7	5.9	12.6	17.4	16.6	14.8	48.8	26.8	8.8	2.9	38.5	10
13	6.6	5.4	12.0	18.8	17.6	15.7	50.1	28.9	9.2	2.9	37.9	13
14	5.9	5.7	11.6	17.2	16.5	15.6	49.4	25.6	9.8	2.7	39.0	22
15	5.3	4.8	10.2	18.3	16.8	16.4	51.2	26.8	9.1	2.7	38.6	19
16	5.3	4.7	10.0	18.6	15.9	16.5	51.9	26.0	9.3	2.8	38.1	17
17	4.8	4.8	9.7	19.2	15.9	16.0	51.1	27.1	9.3	2.8	39.2	8
18	4.8	5.3	10.0	17.3	18.5	17.2	53.0	27.0	7.9	2.1	37.0	1
19	5.4	7.3	12.7	17.6	16.4	18.8	52.7	23.9	8.5	2.1	34.5	1

TABLE 14.—*University Group: Volume of the Segments in Percentage of Total Volume as Derived From Smoothing the Growth Curves*

Age	Segment										
	Cranium	Neck	Head	Chest	Abdomen	Loin	Trunk	Thigh	Calf	Foot	Leg
5	10.7	5.0	15.7	16.4	19.3	17.1	52.8	31.4	7.9	2.1	31.4
6	10.3	5.5	15.8	15.4	18.5	17.2	51.1	22.7	8.1	2.3	33.1
7	9.7	5.8	15.5	14.8	18.0	17.4	50.2	23.4	8.4	2.4	34.2
8	9.2	5.7	14.9	15.5	17.1	17.1	49.7	24.1	8.6	2.5	35.2
9	8.6	5.6	14.2	16.2	16.2	17.1	49.5	25.0	5.6	2.6	38.2
10	5.2	5.3	13.5	17.1	18.2	16.9	50.2	23.8	9.0	2.7	35.6
11	7.8	5.8	13.6	17.3	15.8	16.3	49.1	25.2	9.1	2.8	37.1
12	7.3	6.0	13.3	17.6	16.3	14.7	49.4	25.3	9.2	2.8	37.3
13	6.8	6.2	13.0	17.1	16.5	15.4	48.3	26.5	9.4	2.8	38.7
14	6.2	6.0	12.2	17.1	16.4	15.9	48.9	26.6	9.4	2.8	38.8
15	5.7	5.9	11.6	17.9	16.4	16.0	50.2	26.5	9.1	2.7	38.3
16	5.4	5.7	11.1	18.0	16.6	16.7	50.6	26.9	8.8	2.6	38.3
17	5.0	5.6	10.6	17.5	17.5	17.2	51.7	26.9	8.4	2.8	37.8
18	4.8	5.8	10.6	17.1	17.5	17.2	51.7	27.0	8.2	2.4	37.6
19	4.8	5.8	10.6	16.9	17.3	17.6	51.8	27.1	8.1	2.4	37.6

that there is a lag that comes earlier than indicated by Franzen, which must vary with different subjects. There is also an adolescent spurt between 10 and 12 years of age. It is seen that the rate of growth for the segments varies a great deal. The leg reaches its low point first and starts its increase two years earlier than the trunk. It drops below the trunk at 14 years. The head starts its increase between the leg and the trunk and declines much sooner than either of them. This

TABLE 15.—*Settlement Group: Increase of Body and Segments in Percentage of Volume of Preceding Year*

	Segment											
Age	Cranium	Neck	Head	Chest	Abdomen	Loin	Trunk	Thigh	Calf	Foot	Leg	Body
7.....	2.6	13.8	6.4	25.7	20.9	2.5	15.8	10.0	3.8	14.3	8.7	11.4
8.....	1.9	7.7	4.0	4.5	11.6	11.0	9.1	11.4	4.4	12.5	9.8	8.5
9.....	0.6	4.1	1.9	21.7	8.5	12.1	13.9	0.7	8.5	11.1	3.3	7.8
10.....	1.2	1.9	1.5	0.4	3.6	0	1.3	0.7	8.0	10.0	3.1	2.0
11.....	1.2	18.2	7.9	1.4	13.8	9.6	8.3	3.9	8.0	9.1	5.3	7.1
12.....	1.7	10.6	5.5	13.6	7.6	5.2	8.8	5.1	6.9	8.3	9.4	8.5
13.....	0.6	9.9	4.5	20.3	9.9	1.7	10.8	13.2	5.3	6.1	10.6	9.8
14.....	1.1	4.0	2.5	9.8	9.0	8.2	8.9	15.1	10.0	5.8	13.1	9.6
15.....	1.1	6.4	3.6	10.0	4.7	21.2	11.2	13.8	7.3	5.4	11.6	10.4

TABLE 16.—*University Group: Increase of Body and Segments in Percentage of Volume of Preceding Year*

	Segment											
Age	Cranium	Neck	Head	Chest	Abdomen	Loin	Trunk	Thigh	Calf	Foot	Leg	Body
6.....	5.3	21.4	10.4	3.0	5.5	10.5	8.3	16.7	13.8	16.7	15.9	10.0
7.....	2.5	12.9	6.1	4.2	5.2	9.4	6.3	11.4	12.0	14.3	11.8	8.1
8.....	1.8	7.3	3.9	12.1	1.7	5.1	6.0	10.2	10.7	12.5	10.5	7.2
9.....	0.6	3.9	1.9	12.7	1.6	8.1	7.8	11.6	6.4	11.1	10.3	7.5
10.....	0.5	1.9	1.1	11.8	6.4	4.5	7.5	1.0	12.7	10.0	4.3	6.2
11.....	1.2	17.4	7.8	8.0	4.5	1.4	4.6	13.4	7.0	12.7	11.7	6.8
12.....	1.7	10.9	5.7	10.1	13.0	2.8	8.9	8.2	10.7	8.0	6.6	6.2
13.....	0.6	12.6	6.0	8.2	9.0	5.5	6.9	15.1	11.0	9.0	13.6	9.2
14.....	1.1	6.1	3.6	9.8	9.4	14.5	11.0	10.2	9.8	8.2	10.0	9.7
15.....	1.1	8.2	4.6	15.3	9.7	13.8	12.9	9.4	7.6	6.3	8.6	9.8
16.....	0.6	3.8	2.2	7.5	8.8	8.1	8.1	9.0	8.0	9.4	7.1	7.4
17.....	0	5.2	4.0	5.0	15.3	12.1	10.7	7.4	3.4	3.5	6.3	7.8
18.....	0.6	7.0	2.6	0.8	3.1	6.7	3.5	3.9	0.3	1.1	2.9	3.3
19.....	0	2.3	1.3	0.8	0.8	3.9	1.8	2.0	0	0	1.4	1.6

increase in the head comes mostly in the neck and face, as will be shown later.

In figure 9 is shown the relative rate of growth for the university and settlement groups. Here it appears that in the settlement group the lag is much more pronounced than in the university group. The same is true of the spurt following the lag. In all probability the smaller and more homogeneous the group, the more pronounced will be both the lag and the spurt. When the new method has been applied to subjects throughout their period of growth, much will be disclosed concerning the growth rhythms of the body and the segments which is not apparent from the study of a group as the high points in the growth

of some will come at the low points in the growth of others and thus tend to minimize their full extent or to conceal their presence altogether.

FORMULAS FOR BODY VOLUME

Since the formulas developed by Mumford and Pirquet have been used in determining the specific gravity of the body and the basal metabolism due to body volume, it was decided to test the validity of these formulas by computing the body volume of all subjects measured by water displacement, since this method undoubtedly gives the body volume with greater accuracy. Tables 21 and 22 give the mean variation of these formulas in cubic inches and cubic centimeters and in percentage of the volume as found by water displacement. Figure 10 presents this variation in percentage of total mean volume of each age group.

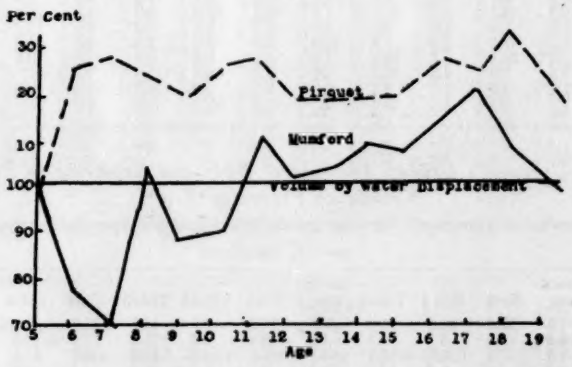

Fig. 10.—Variation of formulas in percentage of volume as found by water displacement.

Mumford's formula that the body volume is equal to that of a cylinder having a diameter equal to the mean of the width and depth of the chest and an altitude equal to the height of the body appears to be more erratic but much more accurate than that of Pirquet. In fact, with the settlement group from 12 to 15 years of age, Mumford's formula varies only about 2 per cent. It is supposed that the settlement boys must be of the same physical type as the boys measured by Mumford, who were children from families employed in the factories of Manchester.

Pirquet's formula that the body volume is equal to the sitting height cubed divided by ten runs consistently high. Pirquet himself recognized this fact and stated that, "only children with considerable fatty tissue would equal the standard while thin children would range about ten per cent below" (p. 14). It appears that if the formula was

TABLE 17.—*Mean Variation in Age and Height of All Boys Measured by Water Displacement*

Age	Settlement Group*				University Group				All			
	No.	Days	In.	Cm.	No.	Days	In.	Cm.	No.	Days	In.	Cm.
5	..	..	...	...	1	0	0.6	1.5	1	0	0.6	1.5
6	2	2	0.4	1.0	..	..	...	...	2	2	0.4	1.0
7	1	2	0.5	1.3	..	..	...	...	1	2	0.5	1.3
8	1	7	0.5	1.3	..	..	...	...	1	7	0.5	1.3
9	3	—9	0.4	1.0	..	..	...	...	3	—9	0.4	1.0
10	5	—12	0.4	1.0	1	24	0.7	1.8	6	—6	0.5	1.3
11	8	0	0.4	1.0	2	42	0.4	1.0	10	8	0.4	1.0
12	7	10	0.5	1.3	10	42	0.5	1.3	17	29	0.5	1.3
13	14	15	0.5	1.3	13	10	0.6	1.5	27	13	0.6	1.4
14	10	2	0.6	1.5	22	—15	0.5	1.3	32	—10	0.5	1.4
15	18	4	0.6	1.5	19	24	0.5	1.3	37	14	0.6	1.4
16	..	..	...	...	17	8	0.8	1.5	17	8	0.6	1.5
17	..	..	...	...	8	—51	0.9	2.3	8	—51	0.9	2.3
18	..	..	...	...	1	—90	1.5	3.8	1	—90	1.5	3.8
19	..	..	...	...	1	—7	0.4	1.0	1	—7	0.4	1.0

* In this group there are two boys 6 years of age, the average age being 2 days over 6 years. The average variation when measured in water is 1 cm.

TABLE 18.—*Mean Sitting Height of All Boys Measured by Water Displacement*

Age	Settlement Group			University Group			All		
	No.	Inches	Cm.	No.	Inches	Cm.	No.	Inches	Cm.
5	..	....	..	1	23.0	58	1	23.0	58
6	2	24.9	63	..	....	..	2	24.9	63
7	1	27.0	69	..	....	..	1	27.0	69
8	1	26.3	67	..	....	..	1	26.3	67
9	3	27.1	69	..	....	..	3	27.1	69
10	5	28.4	72	1	30.0	76	6	28.7	73
11	8	28.6	73	2	28.2	72	10	28.5	72
12	7	29.6	75	10	30.4	77	17	30.0	76
13	14	29.3	74	13	31.1	79	27	30.2	77
14	10	30.8	78	22	32.2	82	32	31.7	80
15	18	31.5	80	19	34.0	86	37	32.7	83
16	..	....	..	17	34.9	89	17	34.9	89
17	..	....	..	8	35.4	90	8	35.4	90
18	..	....	..	1	37.6	96	1	37.6	96
19	..	....	..	1	33.1	84	1	33.1	84

TABLE 19.—*Mean Height and Weight of All Boys Measured by Water Displacement*

Age	Settlement Group					University Group					All				
	No.	In.	Cm.	Lb.	Kg.	No.	In.	Cm.	Lb.	Kg.	No.	In.	Cm.	Lb.	Kg.
5	..	....	...	....	....	1	43.5	110..	47.0	19.7	1	43.6	110	47.0	19.7
6	2	48.0	122	45.5	20.6	..	....	...	....	....	2	48.0	122	45.5	20.6
7	1	49.5	126	57.0	25.9	..	....	...	....	....	1	49.5	125	37.0	25.9
8	1	48.5	123	55.3	26.5	..	....	...	....	....	1	48.5	123	58.3	26.5
9	3	51.6	131	63.4	28.8	..	....	...	....	....	3	51.6	131	63.4	28.8
10	5	54.6	138	66.3	30.1	1	56.2	148	96.0	43.6	6	55.2	140	71.3	32.4
11	8	55.9	142	69.3	31.5	2	56.2	148	72.1	32.8	10	56.0	142	69.9	31.7
12	7	56.7	143	63.5	37.9	10	59.4	151	90.4	41.0	17	58.2	147	87.5	39.7
13	14	58.1	147	79.0	35.9	13	61.8	154	97.3	44.2	27	59.9	152	88.8	40.2
14	10	60.1	153	54.0	38.1	22	63.6	161	107.6	48.9	32	62.5	158	103.4	46.9
15	18	61.1	155	101.4	46.0	19	67.9	172	123.0	55.8	37	64.1	163	112.5	51.0
16	..	....	...	....	....	17	67.9	172	129.7	58.8	17	67.7	172	129.7	58.8
17	..	....	...	....	....	8	69.7	177	138.5	62.8	8	69.7	177	138.5	62.8
18	..	....	...	....	....	1	71.8	182	186.6	70.9	1	71.8	182	156.5	70.9
19	..	....	...	....	....	1	64.6	164	128.0	58.1	1	64.8	164	128.0	58.1

changed to read the cube of the sitting height divided by twelve, it would much more closely approximate the average with growing children.

Extreme cases vary more than 30 per cent, so that with any given subject the volume as found by either formula would be of doubtful value. It might be possible to develop some formula that includes

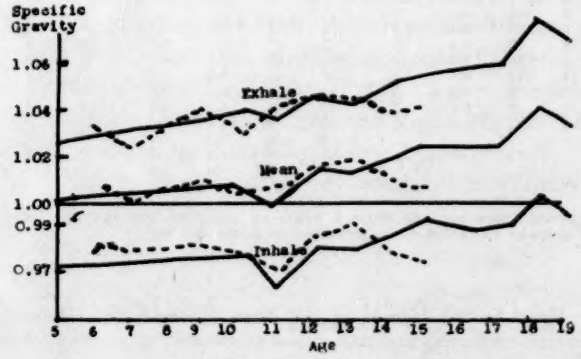

Fig. 11.—Specific gravity of university and settlement groups at inhale and exhale, and the mean. The continuous line indicates the university group; the broken line, the settlement group.

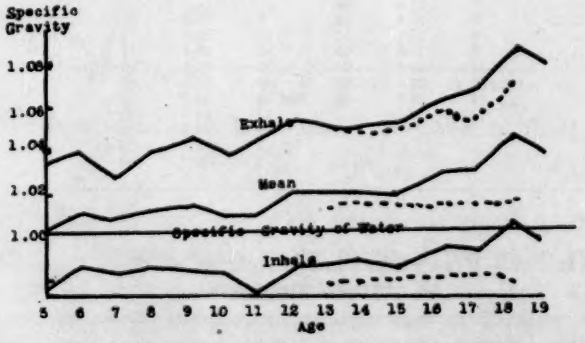

Fig. 12.—Specific gravity of boys measured by water displacement and boys weighed in water by Mumford. The continuous line indicates the specific gravity measured by water displacement; the broken line, that as measured by Mumford.

enough of the variable factors so as to be able to determine the volume or weight of the body, but since both of these may now be determined directly, nothing is to be gained by the construction of such a formula.

SPECIFIC GRAVITY

Since the volume of the body, both at inhale and at exhale, was found and the water used was the same temperature as that of the

TABLE 20.—*Mean Volume of the Body at Inhale and at Exhale for All Boys Measured by Water Displacement*

Age	Settlement Group			University Group			All		
	No.	Exhale, Cubic Inches	Inhale, Cubic Inches	No.	Exhale, Cubic Inches	Inhale, Cubic Inches	No.	Exhale, Cubic Inches	Inhale, Cubic Inches
5	..	.....	.....	1	1,265	1,335	1	1,265	1,338
6	2	1,220	1,281	..	.....	.....	2	1,220	1,281
7	1	1,540	1,611	..	.....	.....	1	1,540	1,611
8	1	1,550	1,642	..	.....	.....	1	1,660	1,642
9	3	1,683	1,784	..	.....	.....	3	1,683	1,784
10	5	1,778	1,675	1	2,560	2,718	6	1,908	2,015
11	8	1,840	1,971	2	1,923	2,075	10	1,857	1,992
12	7	2,202	2,339	10	2,385	2,543	17	2,309	2,459
13	14	2,137	2,276	13	2,585	2,748	27	2,353	2,503
14	10	2,502	2,662	22	2,833	3,018	32	2,729	2,907
15	18	2,697	2,880	19	3,222	3,427	37	2,967	3,161
16	..	.....	.....	17	3,389	3,615	17	3,389	3,615
17	..	.....	.....	8	3,597	3,753	8	3,597	3,753
18	..	.....	.....	1	4,000	4,208	1	4,000	4,208
19	..	.....	.....	1	3,300	3,458	1	3,300	3,458
		Cc.	Cc.		Cc.	Cc.		Cc.	Cc.
5	..	.....	.....	1	20,717	21,912	1	20,717	21,912
6	2	19,980	20,979	..	.....	.....	2	19,980	20,979
7	1	25,221	26,383	..	.....	.....	1	25,221	26,383
8	1	25,548	26,890	..	.....	.....	1	25,548	26,890
9	3	27,563	29,217	..	.....	.....	3	27,563	29,217
10	5	29,118	30,707	1	41,920	44,511	6	31,251	32,992
11	8	30,134	32,276	2	31,490	33,988	10	30,412	32,623
12	7	36,046	38,307	10	39,062	41,650	17	37.817	40,267
13	14	34,995	37,268	13	42,332	45,001	27	38,540	40,990
14	10	42,613	43,593	22	46,399	49,421	32	44,687	47,605
15	18	44,165	47,160	19	52,763	56,125	37	48,585	51,766
16	..	.....	.....	17	55,497	59,202	17	55,497	59,202
17	..	.....	.....	8	58,905	61,459	8	58,905	61,459
18	..	.....	.....	1	65,510	68,911	1	65,510	68,911
19	..	.....	.....	1	54,040	56,631	1	54,040	56,631

TABLE 21.—*Mean Variation of Mumford's and Pirquet's Formulas from the Total Body Volume at Exhale as Found from Water Displacement* *

Age	Settlement Group			University Group			All		
	No.	Mumford	Pirquet	No.	Mumford	Pirquet	No.	Mumford	Pirquet
				Cubic Inches					
5	..	.....	.....	1	—32	—48	1	—32	—48
6	2	—278	320	..	.....	.....	2	—278	320
7	1	—489	428	..	.....	.....	1	—489	428
8	1	49	380	..	.....	.....	1	49	359
9	3	—212	314	..	.....	.....	3	—212	314
10	5	—241	517	1	11	140	6	—199	454
11	8	174	544	2	266	308	10	192	497
12	7	—60	378	10	95	440	17	31	415
13	14	8	390	13	129	448	27	66	413
14	10	—54	434	22	369	538	32	236	505
15	18	57	442	19	369	719	37	217	584
16	..	.....	.....	17	469	896	17	469	896
17	..	.....	.....	8	761	851	8	761	851
18	..	.....	.....	1	309	1,316	1	309	1,316
19	..	.....	.....	1	—12	637	1	—12	637
				Cubic Centimeters					
5	..	.....	.....	1	—524	—786	1	—524	—786
6	2	—4,552	5,241	..	.....	.....	2	—4,552	5,241
7	1	—8,006	7,008	..	.....	.....	1	—8,006	7,008
8	1	802	5,551	..	.....	.....	1	802	5,551
9	3	—3,471	5,142	..	.....	.....	3	—3,471	5,142
10	5	—3,947	8,467	1	180	2,293	6	—3,259	7,436
11	8	2,850	8,910	2	4,356	5,044	10	3,144	8,140
12	7	—983	6,157	10	1,556	7,206	17	508	6,796
13	14	131	6,387	13	2,113	7,336	27	1,081	6,861
14	10	—884	7,107	22	6,043	8,811	32	3,865	8,272
15	18	933	7,238	19	6,043	11,775	37	3,553	9,565
16	..	.....	.....	17	7,680	14,674	17	7,680	14,674
17	..	.....	.....	8	12,463	13,936	8	12,463	13,936
18	..	.....	.....	1	5,060	21,552	1	5,060	21,552
19	..	.....	.....	1	—197	10,433	1	—197	10,433

* Mumford: Body volume equals that of a cylinder the diameter of which is the mean of the width and depth of the chest and the altitude of which is equal to the height of the body. Pirquet: Body volume equals the cube of the sitting height divided by ten.

body, the specific gravity could be determined in each case by comparing the weight of the body with the weight of an equal volume of water at the same temperature (Olsen, p. 646; Spinney, p. 120, and Carhart and Chute, p. 59). By making repeated tests of the water used, it was found that on the average 1 pound of water at 98 F., or body temperature, was equal to 27.6923 cubic inches, instead of 27.87 cubic inches as when the water is free from impurities.

The mean specific gravity at inhale and at exhale for all groups is given in tables 23 and 24 as derived from smoothing the curves. Figures 11 and 12 are constructed directly from the mean of each age group. Figure 11 presents the settlement and the university group, while figure 12 presents both groups combined. Here also is presented

TABLE 22.—*Variation of Formulas in Percentage of Body Volume as Found by Water Displacement*

Age	Settlement Group			University Group			All		
	No.	Mumford	Pirquet	No.	Mumford	Pirquet	No.	Mumford	Pirquet
5.....	..	.....	.....	1	—2.5	—3.8	1	—2.5	—3.8
6.....	2	—22.7	26.1	..	.....	.....	2	—22.7	26.1
7.....	1	—31.8	27.8	..	.....	.....	1	—51.8	27.8
8.....	1	3.1	23.0	..	.....	.....	1	3.1	23.0
9.....	3	—12.6	18.6	..	.....	.....	3	—12.6	18.6
10.....	5	—13.3	28.0	1	0.4	5.5	6	—10.4	23.8
11.....	8	9.5	29.5	2	13.8	16.0	10	10.3	26.7
12.....	7	—2.7	17.1	10	4.0	18.5	17	1.4	18.0
13.....	14	0.4	18.3	13	5.0	17.3	27	2.8	17.8
14.....	10	—2.1	17.3	22	12.6	18.3	32	8.6	18.5
15.....	18	2.1	18.4	19	11.4	22.3	37	7.3	19.7
16.....	..	.....	.....	17	13.8	26.4	17	13.8	26.4
17.....	..	.....	.....	8	21.1	23.6	8	21.1	23.6
18.....	..	.....	.....	1	7.7	33.0	1	7.7	33.0
19.....	..	.....	.....	1	—0.4	19.3	1	—0.4	19.3

the specific gravity as found by Mumford (p. 122) by weighing boys from 13 to 18 years of age in the swimming pool.

It is evident that specific gravity increases with age, from about 1 at 5 to about 1.04 at 18 or 19. This is probably due in part to the greater percentage of muscle and bone and the deposit of mineral matter in the bone at the higher ages, and in part to the fact that the children at the lower ages are unable to exhale as fully as the older children. There is a peculiar drop in the specific gravity at inhale in both groups at 11 years, and a drop in the settlement group for both inhale and exhale at 14 and 15 years of age. This is attributed to the fact that with these boys the chest and abdomen increase rapidly without a corresponding increase in other parts of the body.

MAXIMUM LENGTH OF THE BODY

It was found that subjects measured in water were generally taller than when measured in air. This variation was from 0 to 1½ inches (3.8 cm.). From measurements repeated on twelve boys it was found

that height in water did not vary more than one tenth of an inch (1.4 Gm.), which might be due to an inability to read the graph accurately or to the difference in posture. The heights of these boys varied when measured in air, from which it appeared that a subject would always measure up to a maximum height if measured in water. In searching for a reason why the height varied when measured in water, it became evident that it was due to the fact that the body lost its weight when

TABLE 23.—*Mean Specific Gravity at Inhale and at Exhale as Determined by Smoothing the Curves*

	Settlement Group			University Group			All		
Age	No.	Inhale	Exhale	No.	Inhale	Exhale	No.	Inhale	Exhale
5	..	.....	.....	1	0.974	1.031	1	0.978	1.027
6	2	0.981	1.028	0	0.974	1.032	2	0.980	1.029
7	1	0.982	1.029	0	0.974	1.033	1	0.981	1.032
8	1	0.982	1.030	0	0.974	1.035	1	0.982	1.034
9	3	0.982	1.034	0	0.974	1.036	3	0.981	1.038
10	5	0.980	1.038	1	0.973	1.038	6	0.979	1.040
11	8	0.979	1.030	2	0.970	1.038	10	0.979	1.043
12	7	0.984	1.040	10	0.976	1.042	17	0.982	1.046
13	14	0.965	1.042	13	0.982	1.046	27	0.984	1.047
14	10	0.982	1.042	22	0.986	1.050	32	0.986	1.049
15	18	0.950	1.042	19	0.988	1.053	37	0.987	1.052
18	..	.....	.....	17	0.990	1.058	17	0.990	1.058
17	..	.....	.....	8	0.995	1.056	8	0.995	1.066
18	..	.....	.....	1	0.995	1.075	1	0.998	1.075
19	..	.....	.....	1	1.000	1.080	1	1.000	1.080

TABLE 24.—*Mean Specific Gravity of All Boys From Rough and Smoothed Curves*

	Settlement Group			University Group			All		
Age	No.	Rough	Smooth	No.	Rough	Smooth	No.	Rough	Smooth
5	..	1.000	.....	1	1.001	1.002	1	1.001	1.002
6	2	1.008	1.004	0	.....	1.002	2	1.008	1.004
7	1	1.003	1.005	0	.....	1.003	1	1.003	1.007
8	1	1.009	1.006	0	.....	1.004	1	1.009	1.008
9	3	1.012	1.008	0	.....	1.005	3	1.012	1.009
10	5	1.007	1.009	1	1.009	1.006	6	1.008	1.010
11	8	1.009	1.008	2	1.000	1.004	10	1.007	1.011
12	7	1.019	1.012	10	1.017	1.009	17	1.018	1.012
13	14	1.020	1.013	13	1.013	1.014	27	1.017	1.015
14	10	1.012	1.012	22	1.021	1.019	32	1.018	1.017
15	18	1.009	1.011	19	1.026	1.022	37	1.018	1.020
16	.	.....	.....	17	1.026	1.024	17	1.026	1.024
17	..	.....	.....	8	1.027	1.030	8	1.027	1.030
18	..	.....	....	1	1.043	1.036	1	1.043	1.036
19	..	.....	.....	1	1.035	1.040	1	1.035	1.040

submerged and there was no longer pressure on the cartilaginous pads between the vertebrae and the fleshy pads of the sole and on the arches of the feet. It was evident that if this was correct it should be possible to measure one while lying on a table and secure this same maximum measure. Accordingly, the boys were measured in this position, and it was found that their length was practically the same as when measured in water, regardless of the time of day and the amount of exercise they had taken. In all cases the variation was so slight that it would appear that although the height of a person as ordinarily measured may vary

as much as 1½ inches, it is possible by either of the two methods to secure the true or maximum height of the person regardless of the time of day or the amount of exercise taken. The few cases in which measurements were made in this way are not taken as conclusive evidence, but probably explain the cases found in records of physical measurements in which a boy of growing age appears to have made no gain in height between two birthday measurements. The probability is that he was measured the first time early in the day when his standing

TABLE 25.—*Mean Width and Depth of Chest for All Boys Measured by Water Displacement*

Age	Settlement Group			University Group			All		
	No.	Width	Depth	No.	Width	Depth	No.	Width	Depth
				Inches					
5	..	...	...	1	7.0	5.0	1	7.0	5.0
6	2	5.9	4.1	..	...	...	2	5.9	4.1
7	1	6.0	4.5	..	...	...	1	6.0	4.5
8	1	7.0	6.0	..	...	...	1	7.0	6.0
9	3	6.9	5.0	..	...	...	3	6.9	5.0
10	5	6.9	5.0	1	9.0	6.0	6	7.3	5.2
11	8	7.6	5.7	8	8.5	6.0	10	7.8	5.7
12	7	7.8	5.9	10	8.6	6.8	17	8.2	5.9
13	14	7.7	5.7	13	8.7	6.1	27	8.2	5.9
14	10	8.1	6.2	22	9.3	6.6	32	8.9	6.5
15	18	8.5	6.6	19	9.7	6.8	37	9.1	6.7
16	..	...	...	17	10.1	6.9	17	10.1	6.9
17	..	...	...	8	10.5	7.3	8	10.5	7.3
18	..	...	...	1	10.5	7.0	1	10.5	7.0
19	..	...	...	1	9.5	6.3	1	9.8	6.3
				Centimeters					
5	..	..	..	1	17	13	1	17	13
6	2	15	10	..	..	..	2	15	10
7	1	15	11	..	..	..	1	15	11
8	1	18	15	..	..	..	1	18	15
9	3	18	13	..	..	..	3	18	13
10	5	18	13	1	23	15	6	19	14
11	8	19	14	2	21	15	10	20	14
12	7	20	15	10	22	17	17	21	15
13	14	20	14	13	22	16	27	21	15
14	10	21	16	22	23	17	32	23	17
15	18	22	17	19	25	17	37	23	17
16	..	..	..	17	26	18	17	26	18
17	..	..	..	8	27	18	8	27	18
18	..	..	..	1	27	18	1	27	18
19	..	..	..	1	25	16	1	25	16

height was near his maximum height and the second time late in the day or after taking severe exercise.

IV. THE TOTAL HEAD

Probably the greatest value of the method of measuring by water displacement is that for the first time there is a reasonably exact measure of the size of any segment of the body which is expressed in a single unit of volume. Having this measure, one is able to determine the relation of the segments and the rate at which each segment grows.

The purpose of this part is to show the growth of the total head, which extends from the sternal crest to the top of the head. This segment includes two minor segments, the cranium and the neck. The

division point between the two minor segments is the center of the auditory canal.

The volume of the head as found by water displacement may be less exact than that of other segments of the body. This is due to the fact that most subjects breathe with more difficulty or at least breathe differently when the head is under water. The lung capacity taken while the head was submerged was always less than that taken before. With two of the younger subjects, this difference was nearly 20 cubic inches (327.6 cc.), or about 20 per cent of their lung capacity. In

TABLE 26.—*Lung Capacity and Volume of Arms for All Boys Measured by Water Displacement*

Age	Settlement Group			University Group			All		
	No.	Lungs	Arms	No.	Lungs	Arms	No.	Lungs	Arms
				Measurements in Cubic Inches					
5	..	...	...	1	73	87	1	73	87
6	2	61	118	..	...	...	2	61	118
7	1	71	119	..	...	...	1	71	119
8	1	82	123	..	...	...	1	82	123
9	3	101	129	..	...	...	3	101	129
10	5	97	140	1	158	210	6	107	152
11	8	131	156	2	153	179	10	136	161
12	7	137	173	10	158	198	17	149	185
13	14	139	175	13	163	212	27	151	193
14	10	160	213	22	186	243	32	178	234
15	18	183	203	19	205	262	37	194	233
16	..	...	...	17	226	276	17	226	276
17	..	...	...	8	256	331	8	256	331
18	..	...	...	1	208	300	1	208	300
19	..	...	...	1	158	330	1	158	330
				Measurements in Cubic Centimeters					
5	..	.....	.....	1	1,196	1,425	1	1,196	1,425
6	2	999	1,932	..	.....	.....	2	999	1,932
7	1	1,163	1,949	..	.....	.....	1	1,163	1,949
8	1	1,343	2,014	..	.....	.....	1	1,343	2,014
9	3	1,654	2,113	..	.....	.....	3	1,654	2,113
10	5	1,589	2,293	1	2,588	3,439	6	1,752	2,489
11	8	2,145	2,555	2	2,506	2,931	10	2,227	2,637
12	7	2,244	2,833	10	2,588	3,161	17	2,440	3,030
13	14	2,276	2,866	13	2,669	3,471	27	2,473	3,161
14	10	2,620	3,488	22	3,046	3,979	32	2,915	3,832
15	18	2,997	3,323	19	3,356	4,290	37	3,177	3,816
16	..	.....	.....	17	3,701	4,520	17	3,701	4,520
17	..	.....	.....	8	4,192	5,420	8	4,192	5,420
18	..	.....	.....	1	3,405	4,913	1	3,405	4,913
19	..	.....	.....	1	2,588	5,404	1	2,588	5,404

most cases the difference was about 5 cubic inches (81.9 cc.), and in only the two cases mentioned did it exceed 10 cubic inches (163.8 cc.). If the water pressure on the chest caused each subject to exhale as much more deeply as it prevented him from inhaling more fully, then there would be no error. It being impossible to determine whether an error existed and, if it did, at what point it was made and from which segment the error should be subtracted and to which it should be added, when the computations were made, the volume of the segments was left as recorded by the apparatus.

In presenting the volume of the head and the two minor segments, the volume of the head in cubic inches and cubic centimeters and in

percentage of total volume for all cases combined is shown in figures 13 and 14. The curves presented are taken from tables 1 and 3 and are not the smoothed curves. The curves for the university and settlement groups are taken from tables 31 and 32 and are not smoothed. Figure 13 shows that the settlement group is slightly inferior to the university group at most points, but at 11 years is superior to it. This is probably due to the small size of the two subjects in the university group at 11 years. From 12 to 15 years, the average difference is about 20 cubic inches.

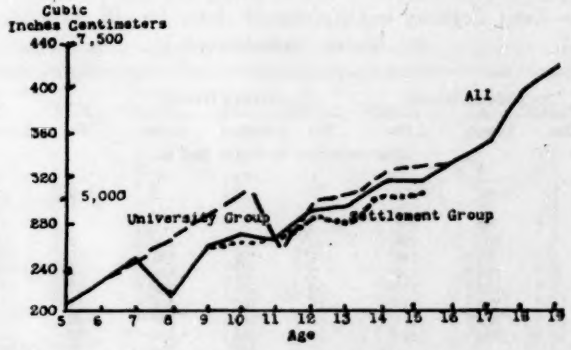

Fig. 13.—Mean volume of the total head.

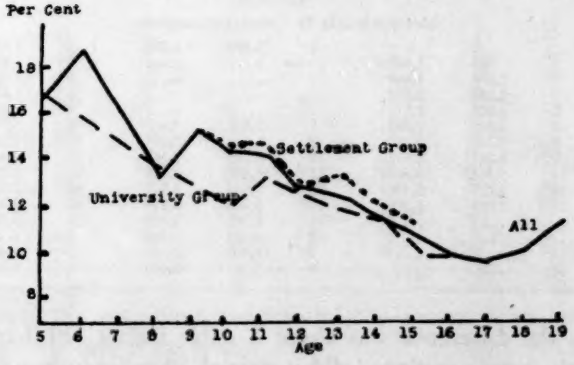

Fig. 14.—Volume of the head in percentage of the total volume.

From figure 14 it appears that the relative size of the head decreases from about 18 per cent at 5 years to about 10 per cent at 18 or 19 years. The head is a larger percentage of the total body with the settlement group than with the university group. Although about 20 cubic inches smaller on the average from 12 to 15 years, it is from 1 to 2 per cent more of the total body volume. As previously stated, the few cases at either end of the curve cause much variation. On this account, the curves for the minor segments were smoothed in the same way as the curve for the body as a whole.

Figure 15 presents the volume of the head and its segments from the smoothed curves given in table 2. The total head increases from about 200 cubic inches (3,275 cc.) at 5 years to about 400 cubic inches

TABLE 27.—*The Cranium: Mean Volume and Mean Height for All Boys Measured by Water Displacement*

Age	Settlement Group			University Group			All		
	No.	Volume	Height	No.	Volume	Height	No.	Volume	Height
	Measurements in Cubic Inches and Inches								
5	..	...	...	1	150	5.0	1	150	5.0
6	2	150	4.5	..	...	...	2	150	4.5
7	1	160	4.6	..	...	...	1	160	4.6
8	1	140	4.6	..	...	...	1	140	4.5
9	3	162	5.0	..	...	...	3	162	5.0
10	5	158	5.2	1	166	5.5	6	159	5.3
11	8	159	5.3	2	140	5.2	10	156	5.3
12	7	167	5.3	10	168	5.2	17	161	5.3
13	14	165	5.2	13	168	5.2	27	167	5.2
14	10	171	5.2	22	164	5.2	32	166	5.2
15	18	170	5.3	19	170	5.3	37	170	5.3
16	..	...	...	17	173	5.3	17	173	5.3
17	..	...	...	8	171	5.4	8	171	5.4
18	..	...	...	1	190	5.1	1	190	5.1
19	..	...	...	1	180	5.4	1	180	5.4
	Measurements in Cubic Centimeters and Centimeters								
5	..	.....	....	1	2,457	12.7	1	2,457	12.7
6	2	2,457	11.4	..	.....	....	2	2,457	11.4
7	1	2,620	11.6	..	.....	....	1	2,620	11.6
8	1	2,293	11.4	..	.....	....	1	2,293	11.4
9	3	2,653	12.7	..	.....	....	3	2,653	12.7
10	5	2,588	13.2	1	2,620	14.0	6	2,603	13.5
11	8	2,604	13.5	2	2,293	13.2	10	2,538	13.5
12	7	2,735	13.5	10	2,588	13.2	17	2,637	13.5
13	14	2,702	13.2	13	2,751	13.2	27	2,735	13.2
14	10	2,800	13.2	22	2,686	13.2	32	2,719	13.2
15	18	2,784	13.5	19	2,784	13.5	37	2,784	13.5
16	..	.....	....	17	2,833	13.5	17	2,833	13.5
17	..	.....	....	8	2,800	13.7	8	2,800	13.7
18	..	.....	....	1	3,112	13.0	1	3,112	13.0
19	..	.....	....	1	2,948	13.7	1	2,948	13.7

TABLE 28.—*The Cranium: Mean Volume and Height in Percentage of the Total Volume and Total Height*

Age	Settlement Group			University Group			All		
	No.	Volume	Height	No.	Volume	Height	No.	Volume	Height
5	..	...	...	1	11.9	11.3	1	11.9	11.3
6	2	12.3	9.2	..	...	...	2	12.3	9.2
7	1	10.4	9.2	..	...	...	1	10.4	9.2
8	1	9.0	9.2	..	...	...	1	9.0	9.2
9	3	9.6	9.6	..	...	...	3	9.6	9.6
10	5	8.9	9.5	1	6.3	9.3	6	8.5	9.4
11	8	8.7	9.2	2	7.3	9.1	10	8.5	9.2
12	7	7.7	9.3	10	6.7	8.7	17	7.1	9.0
13	14	7.8	9.0	13	6.6	8.3	27	7.3	8.6
14	10	7.0	8.5	22	5.9	8.1	32	6.3	8.2
15	18	6.4	8.6	19	5.3	7.9	37	3.8	8.2
16	..	...	...	17	5.3	7.7	17	5.3	7.7
17	..	...	...	8	4.8	7.6	8	4.8	7.6
18	..	...	...	1	4.8	7.0	1	4.8	7.0
19	..	...	...	1	5.4	8.3	1	6.4	8.3

(6,550 cc.) at 19 years. The cranium increases very slowly and the neck more rapidly, so that most of the growth of the total head is found in the neck segment.

Figure 16 gives the volume of the head and its two segments in percentage of total body volume. The neck appears to be about 6 per cent of the total body volume at all ages, or, in other words, the neck grows at just about the same rate as the total body. The cranium, while increasing slightly in size (from 150 to 180 cubic inches [2,457 to 2,948 cc.]), decreases from about 18 per cent to 10.6 per cent. This, of course, is due to the fact that the remainder of the body is growing

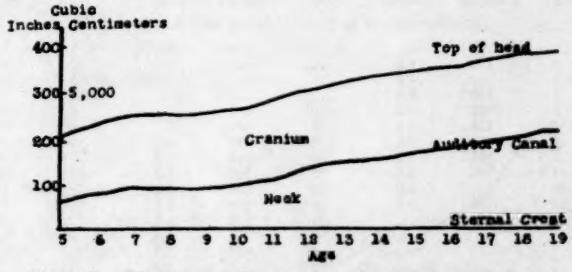

Fig. 15.—Volume of the head and its two segments.

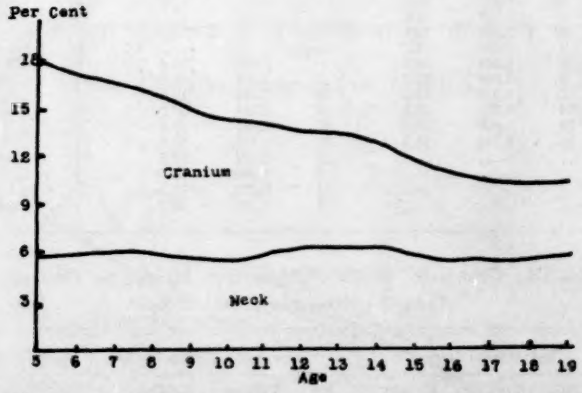

Fig. 16.—Volume of the total head and its two segments in percentage of the total volume.

rapidly while the cranium has practically stopped growing, as it averages only about 1 per cent a year from 8 to 19 years.

In order to show the relative rate of growth for the total head and its two segments, figure 17 is presented, giving the relative rate of growth for each segment in percentage of increase in volume over the volume of the preceding year. The values for this figure are taken from table 6, derived from the smoothed curves of the various segments. From this figure it is evident that the rapid growth of the cranium has ceased, even before school age. The neck is growing rapidly at 5 and 6, but slows down until after 10, when its rate of growth increases

rapidly and remains high until after 13 years of age. Its rate of increase drops to about 4 per cent at 19 years, but is still growing, while the cranium has grown very slightly since the early years. While the neck is having its period of rapid growth, it appears that the part of the cranium adjoining also increases slightly from 11 to 15 years. This may be merely accidental, but this slight growth appears when the two groups are studied separately.

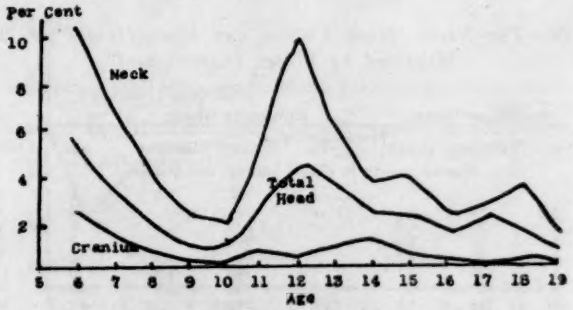

Fig. 17.—Rate of growth of the total head and its two segments.

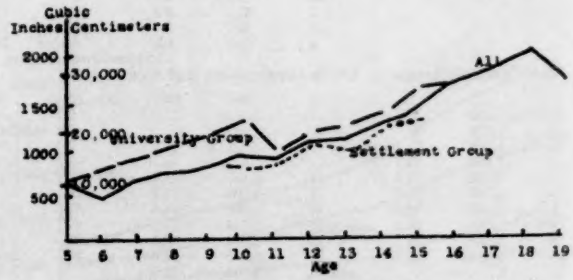

Fig. 18.—Volume of the total trunk.

V. THE TOTAL TRUNK

The total trunk, as discussed in this part, extends from the crotch to the sternal crest. It is divided into three minor segments: the chest, the abdomen and the loin. The division point between the chest and the abdomen is the center of the fifth intercostal space and approximates the lower end of the sternum. The division point between the loin and the abdomen is the center of the navel. These segments include the part of the arm alongside the segments.

Figure 18 presents the growth of the total trunk in cubic inches and cubic centimeters for all cases combined and for the university and settlement groups individually. Figure 19 presents the same material in percentage of total volume. The data for these figures are taken from tables 39 and 40.

The total trunk increases from about 500 cubic inches (8,189 cc.) at 5 years to about 2,000 cubic inches (32,750 cc.) at 18 or 19 years of age. The settlement group is much below the university group, at the extreme points more than 400 cubic inches (6,551 cc.).

Figure 19 shows that the total trunk increases from about 44 per cent at 5 years to about 52 per cent of the total volume at 18 or 19 years. In the case of the settlement group, the mean volume of the trunk not only is less in cubic inches but is also less in percentage

TABLE 29.—*The Neck: Mean Volume and Mean Height for All Boys Measured by Water Displacement*

Age	Settlement Group			University Group			All		
	No.	Volume	Height	No.	Volume	Height	No.	Volume	Height
	Measurements in Cubic Inches and Inches								
5	..	...	...	1	60	4.3	1	60	4.3
6	2	80	4.2	..	...	...	2	80	4.2
7	1	90	4.6	..	...	...	1	90	4.6
8	1	70	4.5	..	...	...	1	70	4.5
9	3	95	4.6	..	...	...	3	95	4.6
10	5	105	5.1	1	150	5.8	6	112	5.2
11	8	108	5.1	2	108	5.2	10	108	5.1
12	7	114	5.3	10	141	5.7	17	130	5.5
13	14	116	6.0	13	137	6.0	27	126	6.0
14	10	132	5.8	22	159	6.5	32	150	6.3
15	18	139	6.3	19	156	6.6	37	147	6.5
16	..	...	...	17	161	6.9	17	161	6.9
17	..	...	...	8	177	6.9	8	177	6.9
18	..	...	...	1	210	7.4	1	210	7.4
19	..	...	...	1	240	8.0	1	240	8.0
	Measurements in Cubic Centimeters and Centimeters								
5	..	.....	....	1	982	10.9	1	982	10.9
6	2	1,310	10.7	..	.....	....	2	1,310	10.7
7	1	1,474	11.7	..	.....	....	1	1,474	11.7
8	1	1,146	11.4	..	.....	....	1	1,146	11.4
9	3	1,556	11.7	..	.....	....	3	1,556	11.7
10	5	1,720	13.0	1	2,457	14.7	6	1,834	13.2
11	8	1,769	13.0	2	1,769	13.2	10	1,769	13.0
12	7	1,867	13.5	10	2,309	14.5	17	2,129	14.0
13	14	1,900	15.2	13	2,243	15.2	27	2,064	15.2
14	10	2,162	14.7	22	2,604	16.5	32	2,457	16.0
15	18	2,276	16.0	19	2,555	16.8	37	2,407	16.6
16	..	.....	....	17	2,637	17.5	17	2,637	17.5
17	..	.....	....	8	2,899	17.5	8	2,899	17.5
18	..	.....	....	1	3,439	18.8	1	3,439	18.8
19	..	.....	....	1	3,930	20.3	1	3,930	20.3

of total volume, showing that the trunk has suffered more than the head, since the head was less in volume but greater in percentage of total body volume.

The study of the growth of the trunk illustrates admirably the inadequacy of presenting the growth of a segment in units of length. From 5 to 19 years the trunk increases from 15 to about 21 inches (37.54 to 53.34 cm.), or 40 per cent, while in volume it increases from about 500 to 2,000 cubic inches, or 400 per cent.

Figure 20 gives the growth of the total trunk in cubic inches and cubic centimeters and the relation of the three minor segments. The material for this figure is taken from table 2. The chest increases

from 150 to 640 cubic inches (2,456 to 10,481 cc.), the abdomen from 162 to 655 cubic inches (2,653 to 10,727 cc.) and the loin from about 200 to 665 cubic inches (3,275 to 10,892 cc.). At the higher ages, the size of the three segments becomes about equal. The chest is smallest in the beginning, but has the greatest increase. This increase from 5 to 19 years is about 425 per cent, which is greater than that of any other segment of the body, with the exception of the thigh, which has an increase of about 500 per cent.

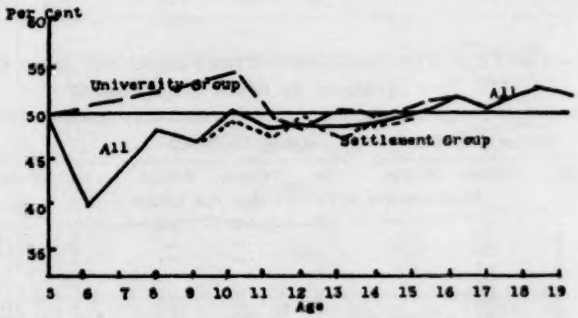

Fig. 19.—Volume of the trunk in percentage of the total volume.

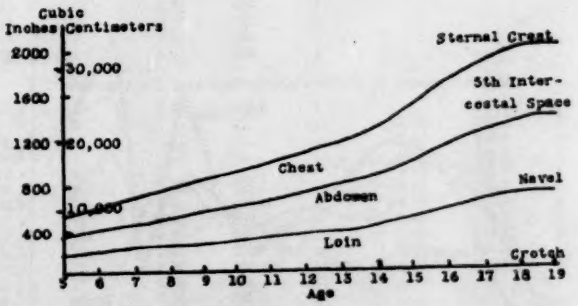

Fig. 20.—Volume of the trunk and its three segments.

Figure 21 presents the same material as figure 20, but in percentage of total body volume. This material is taken directly from table 4. From this figure it is also seen that the three segments of the trunk are about equal in volume, each one ranging from 13 to 17 per cent of the total volume at different ages. The chest varies from 13 to 18 per cent, the abdomen from 14 to 17.5 per cent and the loin from 14 to 17.6 per cent of the total trunk. The total trunk varies from about 43 to 52 per cent of the total body.

Figure 22 presents the rate of growth of the total trunk and the three minor segments in percentage of increase in volume over the volume of the preceding year. The material for this figure is taken

TABLE 30.—*The Neck: Mean Volume and Mean Height in Percentage of Total Volume and Total Height*

Age	Settlement Group			University Group			All		
	No.	Volume	Height	No.	Volume	Height	No.	Volume	Height
5	..	...	...	1	4.7	9.7	1	4.7	9.7
6	2	6.5	8.7	..	...	...	2	6.5	8.7
7	1	5.8	9.2	..	...	...	1	5.8	9.2
8	1	4.5	9.2	..	...	...	1	4.5	9.2
9	3	5.7	8.8	..	...	...	3	5.7	8.8
10	5	5.9	9.2	1	5.9	9.8	6	5.9	9.3
11	8	5.8	9.1	2	5.5	9.2	10	5.8	9.1
12	7	5.3	9.5	10	5.9	9.5	17	5.7	9.5
13	14	5.4	10.3	13	5.4	9.6	27	5.4	10.0
14	10	5.3	9.7	22	5.7	10.1	32	5.6	10.0
15	18	5.2	10.2	19	4.8	9.8	37	5.0	10.0
16	..	...	....	17	4.7	10.1	17	4.7	10.1
17	..	...	....	8	4.9	9.7	8	4.9	9.7
18	..	...	....	1	5.2	10.1	1	5.2	10.1
19	..	...	....	1	7.3	12.3	1	7.3	12.3

TABLE 31.—*The Total Head and Neck: Mean Volume and Mean Height for All Boys Measured by Water Displacement*

Age	Settlement Group			University Group			All		
	No.	Volume	Height	No.	Volume	Height	No.	Volume	Height
	Measurements in Cubic Inches and Inches								
5	..	...	...	1	210	9.3	1	210	9.3
6	2	230	8.7	..	...	...	2	230	8.7
7	1	250	9.2	..	...	...	1	250	9.2
8	1	210	9.0	..	...	...	1	210	9.0
9	3	257	9.6	..	...	...	3	257	9.6
10	5	263	10.2	1	310	11.3	6	271	10.4
11	8	267	10.5	2	248	10.4	10	263	10.5
12	7	281	10.6	10	298	10.9	17	291	10.8
13	14	282	11.3	13	305	11.2	27	293	11.2
14	10	304	11.1	22	322	11.7	32	316	11.5
15	18	308	11.6	19	326	11.9	37	317	11.7
16	..	...	....	17	334	12.2	17	334	12.2
17	..	...	....	8	347	12.2	8	347	12.2
18	..	...	....	1	400	12.5	1	400	12.5
19	..	...	....	1	420	13.4	1	420	13.4
	Measurements in Cubic Centimeters and Centimeters								
5	..	.....	....	1	3,439	23.7	1	3,439	23.7
6	2	3,767	21.8	..	.....	....	2	3,767	21.8
7	1	4,094	23.4	..	.....	....	1	4,094	23.4
8	1	3,439	22.9	..	.....	....	1	3,439	22.9
9	3	4,209	24.4	..	.....	....	3	4,209	24.4
10	5	4,307	25.9	1	5,077	28.7	6	4,438	26.4
11	8	4,372	26.7	2	4,061	26.4	10	4,339	26.7
12	7	4,602	26.9	10	4,880	27.7	17	4,765	27.4
13	14	4,618	28.7	13	4,996	28.4	27	4,798	28.4
14	10	4,980	28.2	22	5,273	29.7	32	5,175	29.2
15	18	5,044	29.4	19	5,339	30.2	37	5,191	29.7
16	..	.....	....	17	5,469	31.0	17	5,469	31.0
17	..	.....	....	8	5,683	31.0	8	5,683	31.0
18	..	.....	....	1	6,551	31.8	1	6,551	31.8
19	..	.....	....	1	6,878	34.0	1	6,878	34.0

TABLE 32.—*The Total Head and Neck: Mean Volume and Mean Height in Percentage of Total Volume and Total Weight*

Age	Settlement Group			University Group			All		
	No.	Volume	Height	No.	Volume	Height	No.	Volume	Height
5	..	....	....	1	16.6	21.0	1	16.6	21.0
6	2	18.8	17.9	..	....	....	2	18.8	17.9
7	1	16.2	16.4	..	....	....	1	16.2	16.4
8	1	13.5	18.4	..	....	....	1	13.5	18.4
9	3	15.3	18.5	..	....	....	3	15.3	18.5
10	5	14.8	13.6	1	12.1	19.1	6	14.4	18.7
11	8	14.6	18.6	2	12.9	18.3	10	14.3	18.5
12	7	13.0	18.6	10	12.6	18.2	17	12.8	18.4
13	14	13.2	19.2	13	12.0	18.0	27	12.6	18.6
14	10	12.3	18.2	22	11.6	18.3	32	11.8	18.2
15	18	11.5	18.7	19	10.2	17.6	37	10.8	18.2
16	..	....	....	17	10.0	17.8	17	10.0	17.8
17	..	....	....	8	9.7	17.3	8	9.7	17.3
18	..	....	....	1	10.0	17.1	1	10.0	17.1
19	..	....	....	1	12.7	20.6	1	12.7	20.6

from table 6. The lag in growth is apparent from 5 to 11 years, and then an ever-increasing rate of growth to 15 years of age. In the case of the trunk, the adolescent spurt in growth is not so marked as with the leg and head. With the trunk it covers a period of four years, while for the head and leg it is confined to about two years. After 16 there is a rapid decline to about 2 per cent at 19 years.

The volume of the chest appears to be increasing more rapidly than the other segments in the early years, but this increase is erratic.

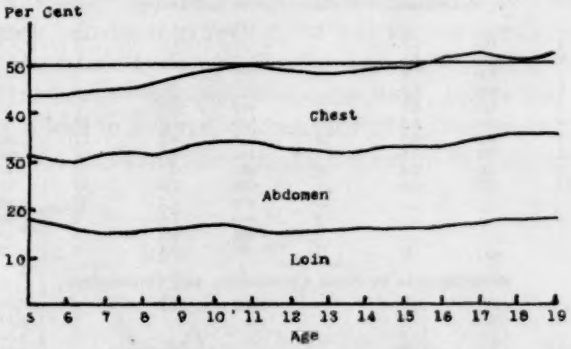

Fig. 21.—Volume of the trunk and its three segments in percentage of the total volume.

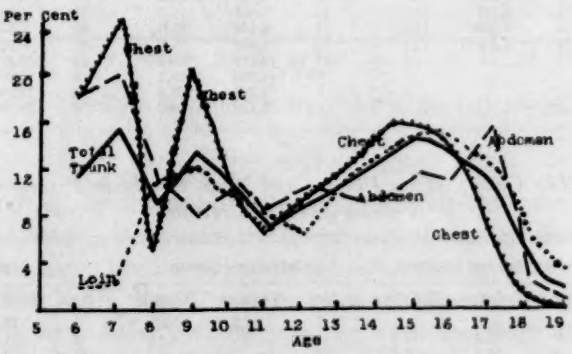

Fig. 22.—Rate of growth of the trunk and its three segments.

The chest has its adolescent spurt before the other segments of the trunk as well as an earlier decline.

The abdomen shows a lag in growth in the early years, but apparently has no adolescent spurt unless the rise between 16 and 17 could be termed such. This segment appears to maintain a uniform rate of growth from 8 to 16 years of age.

The loin appears to have two spurts, one from 7 to 8, while the other two segments are declining, and another beginning about 12 and increasing at about the same rate as the chest. The rate of growth of this segment was lowest at 5 years, but was highest at 19.

Figure 23 shows the comparative rate of growth of the trunk in the university and settlement groups. There is a drop in the settlement group with the low point at 10 years, while with the university group

TABLE 33.—*The Chest: Mean Volume and Mean Height for All Boys Measured by Water Displacement*

Age	Settlement Group			University Group			All		
	No.	Volume	Height	No.	Volume	Height	No.	Volume	Height
	Measurements in Cubic Inches and Inches								
5	..	...	...	1	185	4.8	1	185	4.8
6	2	135	5.3	..	...	...	2	135	5.3
7	1	230	6.5	..	...	...	1	230	6.5
8	1	200	5.5	..	...	...	1	200	5.5
9	3	293	6.0	..	...	...	3	293	6.0
10	5	273	6.1	1	410	6.5	6	296	6.2
11	8	286	6.2	2	330	5.5	10	295	6.0
12	7	409	6.2	10	414	6.3	17	412	6.3
13	14	376	6.2	13	440	6.3	27	407	6.3
14	10	461	6.8	22	491	6.7	32	481	6.7
15	18	515	6.8	19	590	7.0	37	554	6.9
16	..	...	...	17	624	7.3	17	624	7.3
17	..	...	...	8	690	7.5	8	690	7.5
18	..	...	...	1	690	8.1	1	690	8.1
19	..	...	...	1	580	6.4	1	580	6.4
	Measurements in Cubic Centimeters and Centimeters								
5	..	.....	....	1	3,030	12.2	1	3,030	12.2
6	2	2,211	13.5	..	.....	....	2	2,211	13.5
7	1	3,767	16.5	..	.....	....	1	3,767	16.5
8	1	3,275	14.0	..	.....	....	1	3,275	14.0
9	3	4,798	15.2	..	.....	....	3	4,798	15.2
10	5	4,471	15.5	1	6,715	16.5	6	4,847	15.8
11	8	4,684	15.8	2	5,404	14.0	10	4,831	15.2
12	7	6,698	15.8	10	6,780	16.0	17	6,747	16.0
13	14	6,157	15.8	13	7,206	16.0	27	6,666	16.0
14	10	7,550	17.3	22	8,040	17.0	32	7,876	17.0
15	18	8,402	17.3	19	9,662	17.8	37	9,072	17.5
16	..	.....	....	17	10,218	18.5	17	10,218	18.5
17	..	.....	....	8	11,300	19.1	8	11,300	19.1
18	..	.....	....	1	11,300	20.6	1	11,300	20.6
19	..	.....	....	1	9,499	16.3	1	9,499	16.3

TABLE 34.—*The Chest: Mean Volume and Mean Height in Percentage of Total Volume and Total Height*

Age	Settlement Group			University Group			All		
	No.	Volume	Height	No.	Volume	Height	No.	Volume	Height
5	..	....	....	1	14.6	10.9	1	14.6	10.9
6	2	11.0	10.8	..	....	....	2	11.0	10.8
7	1	14.9	13.0	..	....	....	1	14.9	13.0
8	1	12.8	11.2	..	....	....	1	12.8	11.2
9	3	17.4	11.5	..	....	....	3	17.4	11.5
10	5	15.3	11.1	1	16.0	11.0	6	15.4	11.1
11	8	15.4	11.0	2	17.1	9.7	10	15.7	10.7
12	7	18.4	11.0	10	17.4	10.6	17	17.8	10.7
13	14	17.6	10.6	13	16.8	10.2	27	17.2	10.4
14	10	18.1	11.2	22	17.2	10.4	32	17.5	10.6
15	18	18.8	11.1	19	18.3	10.4	37	18.6	10.7
16	..	....	....	17	18.6	10.6	17	18.6	10.6
17	..	....	....	8	19.2	10.7	8	19.2	10.7
18	..	....	....	1	17.3	11.1	1	17.3	11.1
19	..	....	....	1	17.6	9.8	1	17.6	9.8

there appears to be no drop until after 10, with the low point at 11 years. Neither the lag nor the spurt is so evident with the university group as with the settlement group.

It would seem that from 5 to 11 years of age there are marked growth rhythms in the segments, and that the subjects are at about the same stage of development, so that these rhythms appear in the growth norm. After this time the individuals are evidently separated in development so that the high point of one growth curve strikes the low point of another, so that a rather regular group curve is produced.

It is evident that this method of measurement is able to show the growth rhythms of the segments very much in detail. In all probability, when measurements have been made on the same subjects over a period of years, each individual growth curve will show a number of lags and spurts for the whole body and for the various segments. In cases of illness, when there is not only a slowing down in the rate of growth but an actual loss in volume, this method of measurement will be able to point out the segments affected and the extent of their loss.

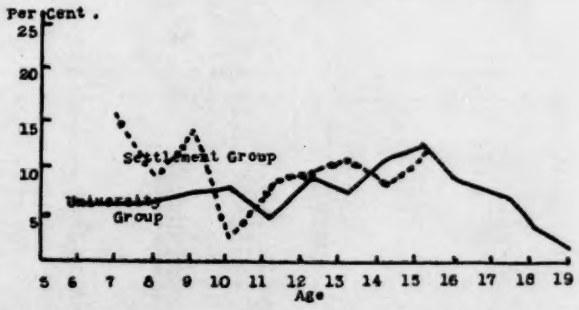

Fig. 23.—Rate of growth of the trunk in the two groups.

VI. THE TOTAL LEG

The total leg, as discussed in this part, extends from the sole of the foot to the crotch. It includes the lower part of the forearm and hand, which extend along the leg when the subject stands in a natural upright position. The leg is divided into three minor segments: the thigh, the calf and the foot. The division point between the thigh and the calf is the center of the knee joint on the inside of the leg. The division point between the calf and the foot is the ankle joint as determined on the inside of the ankle.

Figure 24 presents the growth of the total leg in cubic inches and cubic centimeters. The material for this figure is taken from table 47 and not from the smoothed curve. The total leg increases from about 400 to about 1,400 cubic inches (6,551 to 22,928 cc.) from 5 to 18 or 19 years of age. In the settlement group it is about 200 cubic inches (3,275 cc.) below the university group.

Figure 25 presents the same material as figure 24, but in percentage of the total body volume. It appears that with the settlement group,

especially the very young boys, the leg is a very large percentage of the body. With these same boys it was found that the trunk was a rather small percentage of the body. For both the university and the settle-

TABLE 35.—*The Abdomen: Mean Volume and Mean Height for All Boys Measured by Water Displacement*

Age	Settlement Group			University Group			All		
	No.	Volume	Height	No.	Volume	Height	No.	Volume	Height
	Measurements in Cubic Inches and Inches								
5	..	...	...	1	240	5.3	1	240	5.3
6	2	145	6.0	..	...	...	2	145	6.0
7	1	240	6.3	..	...	...	1	240	6.3
8	1	290	5.5	..	...	...	1	290	5.5
9	3	272	5.9	..	...	...	3	272	5.9
10	5	325	7.0	1	400	6.2	6	337	6.9
11	8	329	6.0	2	330	5.9	10	330	6.0
12	7	389	6.6	10	396	6.5	17	393	6.5
13	14	359	6.1	13	454	6.9	27	405	6.4
14	10	427	6.6	22	466	7.0	32	454	6.9
15	18	480	6.6	19	532	7.5	37	482	7.1
16	..	...	...	17	580	7.7	17	580	7.7
17	..	...	...	8	576	7.7	8	576	7.7
18	..	...	...	1	740	9.2	1	740	9.2
19	..	...	...	1	540	7.0	1	540	7.0
	Measurements in Cubic Centimeters and Centimeters								
5	..	.....	....	1	3,930	13.5	1	3,930	13.5
6	2	2,375	15.2	..	.....	....	2	2,375	15.2
7	1	3,930	16.0	..	.....	....	1	3,930	16.0
8	1	4,749	14.0	..	.....	....	1	4,749	14.0
9	3	4,454	15.0	..	.....	....	3	4,454	15.0
10	5	5,322	17.9	1	6,551	15.8	6	5,518	17.5
11	8	5,388	15.2	2	5,404	14.0	10	5,404	15.2
12	7	6,370	16.8	10	6,501	16.5	17	6,436	16.6
13	14	5,879	15.5	13	7,426	17.5	27	6,633	16.3
14	10	6,992	16.8	22	7,631	17.8	32	7,426	17.5
15	18	7,042	16.8	19	8,712	19.1	37	7,893	18.0
16	..	.....	....	17	9,499	19.6	17	9,499	19.6
17	..	.....	....	8	9,433	19.6	8	9,433	19.6
18	..	.....	....	1	12,119	23.4	1	12,119	23.4
19	..	.....	....	1	8,844	17.8	1	8,844	17.8

TABLE 36.—*The Abdomen: Mean Volume and Mean Height in Percentage of Total Volume and Total Height*

Age	Settlement Group			University Group			All		
	No.	Volume	Height	No.	Volume	Height	No.	Volume	Height
5	..	....	....	1	19.0	12.0	1	19.0	12.0
6	2	11.9	12.4	..	....	....	2	11.9	12.4
7	1	15.6	12.6	..	....	....	1	15.6	12.6
8	1	18.6	11.2	..	....	....	1	18.6	11.2
9	3	16.1	11.4	..	....	....	3	16.1	11.4
10	5	18.4	12.7	1	15.6	10.6	6	17.9	12.4
11	8	17.8	10.6	2	17.1	10.4	10	17.7	10.6
12	7	17.7	11.6	10	16.6	10.8	17	17.0	11.1
13	14	16.7	10.3	13	17.6	11.0	27	17.1	10.7
14	10	17.1	10.9	22	16.5	10.9	32	16.7	10.9
15	18	16.0	10.6	19	16.5	11.1	37	16.2	10.9
16	..	....	....	17	16.8	11.3	17	16.8	11.3
17	..	....	....	8	15.9	10.9	8	15.9	10.9
18	..	....	....	1	18.5	12.5	1	18.5	12.5
19	..	....	....	1	16.4	10.8	1	16.4	10.8

ment groups, the leg remains around 38 or 39 per cent from 11 to 17 years of age. It appears that for the boys of the lower ages who are undernourished, the leg is far more important to the individual than the trunk.

Figure 26 gives the growth of the total leg in cubic inches and cubic centimeters and the relation of the three minor segments to the whole leg. The total leg increases from about 400 to 1,400 cubic inches (6,551 to 22,928 cc.), the thigh from less than 300 cubic inches (4,913 cc.) to more than 1,000 cubic inches (16,377 cc.), the calf from 125 cubic inches (2,047 cc.) to more than 300 cubic inches (4,913 cc.), and the foot from 30 to 90 cubic inches (491 to 1,474 cc.). The thigh is the largest of the minor segments of the body, while the foot is generally the smallest.

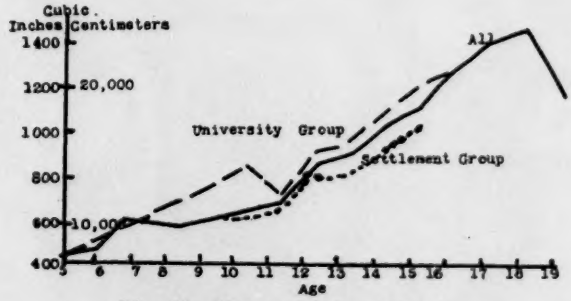

Fig. 24.—Volume of the total leg.

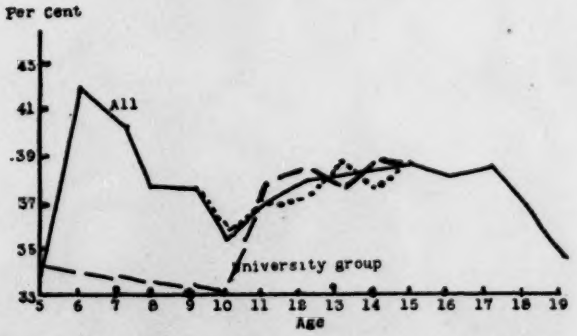

Fig. 25.—Volume of the leg in percentage of the total volume.

Figure 27 gives the same material as figure 26 but in percentage of the total body volume. The material for these figures is taken from tables 2 and 4. It is seen that the thigh is from 24 to 27 per cent of the total volume at all ages, the calf from 8 to 10 per cent, and the foot from 2.5 to about 3 per cent.

Figure 28 gives the rate of growth of the total leg and the three minor segments in percentage increase in volume over the volume of the preceding year. The material for this figure is taken from table 6. Between 5 and 6 years of age, the whole leg grows more than 16 per cent. This rate of growth decreases rapidly and reaches the low point

of the lag, about 4 per cent, at 9 years, and then shows the spurt from 9 to 12 years, remains above 10 per cent until after 16 years, and then rapidly decreases to 1 per cent at 19 years.

TABLE 37.—*The Loin: Mean Volume and Mean Height for All Boys Measured by Water Displacement*

Age	Settlement Group			University Group			All		
	No.	Volume	Height	No.	Volume	Height	No.	Volume	Height
	Measurements in Cubic Inches and Inches								
5	..	...	...	1	200	4.8	1	200	4.8
6	2	210	6.0	..	...	...	2	210	6.0
7	1	200	3.8	..	...	...	1	200	3.8
8	1	270	4.5	..	...	...	1	270	4.5
9	3	223	4.2	..	...	...	3	223	4.2
10	5	283	5.0	1	590	6.5	6	334	5.3
11	6	283	5.5	2	290	5.4	10	284	5.5
12	7	394	4.7	10	357	5.5	17	335	5.2
13	14	292	4.6	13	482	5.2	27	346	4.9
14	10	354	5.2	22	447	5.7	32	418	5.6
15	18	389	5.4	19	530	6.2	37	463	5.8
16	..	...	...	17	555	6.6	17	555	6.6
17	..	...	...	8	581	6.4	8	581	6.4
18	..	...	...	1	690	7.7	1	690	7.7
19	..	...	...	1	620	7.0	1	620	7.0
	Measurements in Cubic Centimeters and Centimeters								
5	..	.....	....	1	3,275	12.2	1	3,275	12.2
6	2	3,439	15.2	..	.....	....	2	3,439	15.2
7	1	3,275	9.7	..	.....	....	1	3,275	9.7
8	1	4,422	11.4	..	.....	....	1	4,422	11.4
9	3	3,652	10.7	..	.....	....	3	3,652	10.7
10	5	4,635	12.7	1	9,662	16.5	6	5,469	13.5
11	8	4,635	14.0	2	4,749	13.7	10	4,651	14.0
12	7	4,980	11.9	10	5,846	14.0	17	5,486	13.2
13	14	4,782	11.7	13	7,893	13.2	27	5,666	12.5
14	10	5,797	13.2	22	7,320	14.5	32	6,845	14.2
15	18	6,370	13.7	19	8,680	15.8	37	7,582	14.7
16	..	.....	....	17	9,089	16.8	17	9,089	16.8
17	..	.....	....	8	9,513	16.3	8	9,513	16.3
18	..	.....	....	1	11,300	19.6	1	11,300	19.6
19	..	.....	....	1	10,154	17.8	1	10,154	17.8

TABLE 38.—*The Loin: Mean Volume and Mean Height in Percentage of Total Volume and Total Height*

Age	Settlement Group			University Group			All		
	No.	Volume	Height	No.	Volume	Height	No.	Volume	Height
5	..	....	....	1	15.8	10.9	1	15.8	10.9
6	2	17.2	12.4	..	....	....	2	17.2	12.4
7	1	13.0	7.6	..	....	....	1	13.0	7.6
8	1	17.3	9.2	..	....	....	1	17.3	9.2
9	3	13.3	8.0	..	....	....	3	13.3	8.0
10	5	15.9	9.0	1	23.0	11.0	6	17.1	9.3
11	8	15.5	9.7	2	15.1	9.5	10	15.4	9.7
12	7	11.4	6.7	10	14.9	9.2	17	14.4	8.8
13	14	13.7	7.8	13	15.7	8.4	27	14.6	8.1
14	10	14.3	8.6	22	15.6	8.9	32	15.2	8.8
15	18	14.7	8.8	19	16.4	9.2	37	15.6	9.0
16	..	....	....	17	16.5	9.7	17	16.5	9.7
17	..	....	....	8	16.0	9.0	8	16.0	9.0
18	..	....	....	1	17.2	10.5	1	17.2	10.5
19	..	....	....	1	18.8	10.8	1	18.8	10.8

The thigh, which increases about 22 per cent between 5 and 6 years of age, rapidly decreases to less than 1 per cent at 9 years and then rapidly rises to 16 per cent at 12 years and remains above 12 per cent

until after 16 years, when it rapidly decreases to less than 2 per cent at 19 years and is the only segment of the leg that is growing perceptibly at that time. The lag and the adolescent spurt are pronounced in this segment.

The calf grows at a rate of about 4 per cent from 5 to 8 years; it then rises to 12 per cent at 11 years, decreases gradually until after 16 years and then rapidly decreases to zero at 19. There is no growth lag indicated in the calf, and the adolescent spurt begins at about 8 years, the earliest of any segment.

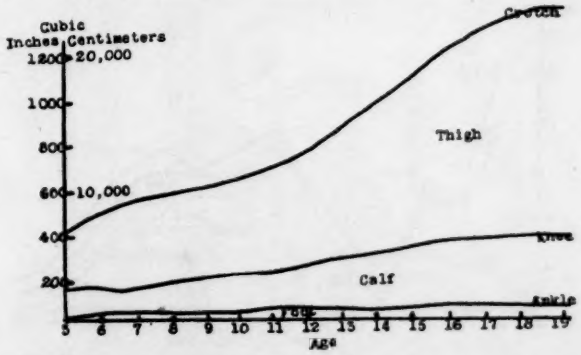

Fig. 26.—Volume of the leg and its three segments.

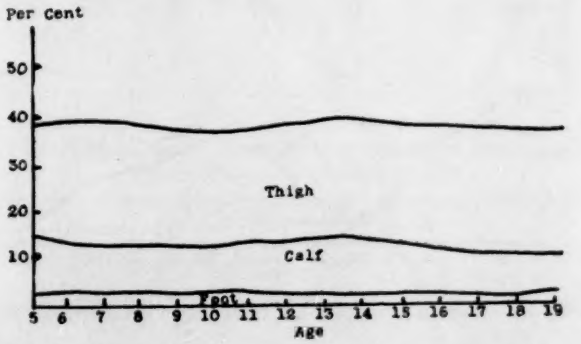

Fig. 27.—Volume of the leg and its segments in percentage of the total volume.

The foot is on the decline from the start, and only at 11 years shows any sign of increasing its rate of growth. After 16 years it drops rapidly.

Figure 29 shows the rate of growth of the total leg for the two groups studied. The growth lag comes early with the settlement group, and the adolescent spurt is not so pronounced as with the university group.

The settlement group has shown both the growth lag and the adolescent spurt in each of the three major segments, while the university

group showed both in the head and leg segments but very little in the trunk. Of the minor segments the cranium and the feet are the only ones not showing a spurt.

VII. SUMMARY

The purpose of this study has been to present a new method of studying physical growth by means of water displacement. There are certain preliminary steps through which all investigations must necessarily pass which have not been reported in the study.

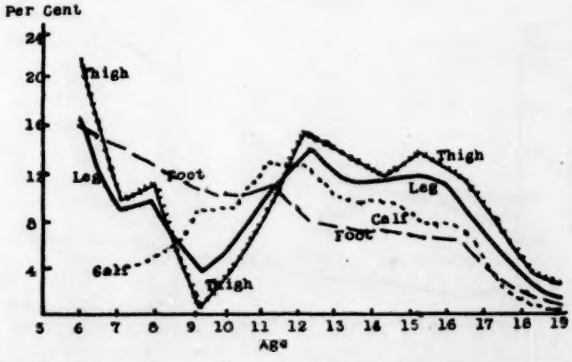

Fig. 28.—Rate of growth of the leg and its three segments.

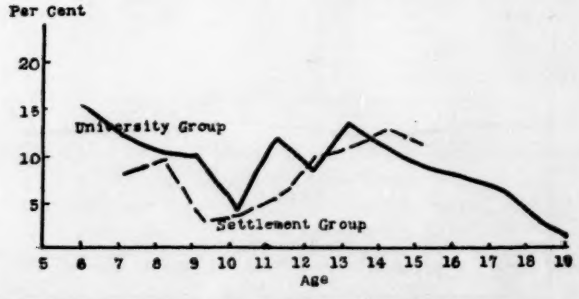

Fig. 29.—Rate of growth of the total leg in the two groups.

FINDINGS

The points of outstanding interest that have been brought out by this study are as follows:

1. A connection was made between the use of water displacement in determining the volume of the body and its segments and the study of physical growth.

2. An apparatus for using water displacement was constructed, which would measure and record by means of a graph the length and volume of the segments in a period of approximately eight minutes.

3. By making detailed measurements on one hundred and sixty-four boys from 5 to 19 years of age, growth norms were determined from the mean of each age group, showing the growth of the whole

TABLE 39.—*The Total Trunk: Mean Volume and Mean Height for All Boys Measured by Water Displacement*

Age	Settlement Group			University Group			All		
	No.	Volume	Height	No.	Volume	Height	No.	Volume	Height
	Measurements in Cubic Inches and Inches								
5	..	.....	....	1	625	14.9	1	625	14.9
6	2	490	17.3	..	.....	....	2	490	17.3
7	1	670	16.6	..	.....	....	1	670	16.6
8	1	760	15.5	..	.....	....	1	760	15.5
9	3	788	16.1	..	.....	....	3	788	16.1
10	5	881	18.1	1	1,400	19.2	6	967	18.3
11	8	896	17.7	2	950	16.8	10	909	17.5
12	7	1,101	17.6	10	1,167	18.3	17	1,159	18.0
13	14	1,028	16.8	13	1,300	18.4	27	1,160	17.6
14	10	1,252	18.6	22	1,404	19.4	32	1,357	19.1
15	18	1,338	18.8	19	1,652	20.7	37	1,499	19.8
16	..	.....	....	17	1,759	21.6	17	1,759	21.6
17	..	.....	....	8	1,847	21.6	8	1,847	21.6
18	..	.....	....	1	2,120	25.0	1	2,120	25.0
19	..	.....	....	1	1,740	20.4	1	1,740	20.4
	Measurements in Cubic Centimeters and Centimeters								
5	..	.....	....	1	10,233	37.9	1	10,233	37.9
6	2	8,025	44.0	..	.....	....	2	8,025	44.0
7	1	10,973	42.1	..	.....	....	1	10,973	42.1
8	1	12,446	39.4	..	.....	....	1	12,446	39.4
9	3	12,905	40.9	..	.....	....	3	12,905	40.9
10	5	14,427	46.0	1	22,928	48.8	6	15,837	46.5
11	8	14,673	45.0	2	15,558	42.6	10	14,886	44.5
12	7	18,031	44.7	10	19,113	46.5	17	18,981	45.7
13	14	16,836	42.6	13	21,290	46.7	27	18,998	44.7
14	10	20,504	47.2	22	22,994	49.3	32	22,224	48.6
15	18	21,912	47.7	19	27,055	52.6	37	24,549	50.3
16	..	.....	....	17	28,807	54.8	17	28,807	54.8
17	..	.....	....	8	30,082	54.8	8	30,082	54.8
18	..	.....	....	1	34,710	63.5	1	34,710	63.5
19	..	.....	....	1	28,496	51.8	1	28,496	51.8

TABLE 40.—*The Total Trunk: Mean Volume and Mean Height in Percentage of Total Volume and Total Height*

Age	Settlement Group			University Group			All		
	No.	Volume	Height	No.	Volume	Height	No.	Volume	Height
5	..	....	....	1	49.4	33.7	1	49.4	33.7
6	2	40.1	35.6	..	....	....	2	40.1	35.6
7	1	43.5	33.2	..	....	....	1	43.5	33.2
8	1	48.7	31.6	..	....	....	1	48.7	31.6
9	3	46.8	30.9	..	....	....	3	46.8	30.9
10	5	49.6	32.9	1	54.7	32.6	6	50.4	32.8
11	8	48.6	31.3	2	49.4	29.6	10	48.8	31.0
12	7	49.9	30.8	10	48.8	30.5	17	49.2	30.6
13	14	48.0	28.8	13	50.1	29.6	27	49.0	29.1
14	10	49.9	30.4	22	49.4	30.2	32	49.5	30.3
15	18	49.5	30.4	19	51.2	30.8	37	50.4	30.6
16	..	....	....	17	51.9	31.6	17	51.9	31.6
17	..	....	....	8	51.1	30.6	8	51.1	30.6
18	..	....	....	1	53.0	34.1	1	53.0	34.1
19	..	....	....	1	52.7	31.4	1	52.7	31.4

body and of each of its segments. These norms were smoothed, and the values as found in table 2 were presented as tentative growth norms of the whole body and the segments in terms of volume for an average or unselected group.

4. By measuring a well nourished group from the Laboratory Schools and a poorly nourished group from the University Settlement, it was possible to point out detailed differences in the groups. The cranium and the foot are the only segments that are practically equal in volume in the settlement and university groups. These segments are a larger percentage of the total body in the settlement group than in the university group. The settlement group is much lower than the university group in volume of all other segments, the greatest difference

TABLE 41.—*The Thigh: Mean Volume and Length of All Boys Measured by Water Displacement*

Age	Settlement Group			University Group			All		
	No.	Volume	Height	No.	Volume	Height	No.	Volume	Height
	Measurements in Cubic Inches and Inches								
5	..	...	....	1	299	8.0	1	299	8.0
6	2	320	9.7	..	...	....	2	320	9.7
7	1	448	10.2	..	...	....	1	448	10.2
8	1	404	10.7	..	...	....	1	404	10.7
9	3	418	11.8	..	...	....	3	418	11.8
10	5	416	11.8	1	585	12.8	6	444	12.0
11	8	445	12.9	2	485	13.4	10	453	13.0
12	7	554	13.1	10	641	14.0	17	605	13.6
13	14	582	13.8	13	670	15.0	27	606	14.4
14	10	652	14.2	22	749	15.1	32	719	14.8
15	18	739	14.4	19	858	15.5	37	800	15.0
16	..	...	....	17	886	15.9	17	886	15.9
17	..	...	....	8	973	17.1	8	973	17.1
18	..	...	....	1	1,080	16.3	1	1,080	16.3
19	..	...	....	1	790	14.2	1	790	14.2
	Measurements in Cubic Centimeters and Centimeters								
5	..	.....	....	1	4,896	20.3	1	4,896	20.3
6	2	5,241	24.7	..	.....	....	2	5,241	24.7
7	1	7,336	25.9	..	.....	....	1	7,336	25.9
8	1	6,616	27.2	..	.....	....	1	6,616	27.2
9	3	6,846	29.9	..	.....	....	3	6,846	29.9
10	5	6,813	29.9	1	9,581	32.5	6	7,272	30.5
11	8	7,288	32.8	2	7,943	34.0	10	7,409	33.0
12	7	9,073	33.5	10	10,497	35.6	17	9,908	34.5
13	14	9,532	35.0	13	10,973	38.1	27	9,924	36.6
14	10	10,678	36.1	22	12,236	38.4	32	11,774	37.6
15	18	12,103	36.6	19	14,051	39.4	37	13,102	38.1
16	..	.....	....	17	14,509	40.4	17	14,509	40.4
17	..	.....	....	8	15,934	43.5	8	15,934	43.5
18	..	.....	....	1	17,687	41.4	1	17,687	41.4
19	..	.....	....	1	12,937	36.1	1	12,938	36.1

being found in the trunk. In these segments both groups are about equal when the volume of these segments has been reduced to the percentage of the total volume.

5. By reducing the volume of each segment to the percentage of the total volume, it was possible to show the relative size of the segments at different ages. The head decreases from about 18 per cent at 5 to about 10 per cent at 19 years. The neck remains about 6 per cent at all ages, while the cranium decreases from about 12 per cent to about 4 or 5 per cent. The trunk increases from about 44 per cent at 5 to about 52 per cent at 19 years. The abdomen remains almost constant, increasing only about 1 per cent between 7 and

19 years. The chest and loin increase about 3 per cent from 5 to 19 years. At this latter age the three segments of the trunk are practically equal, being around 17 per cent of the total body volume. The leg remains almost constant, around 39 per cent of the total body volume. The thigh fluctuates from 25 to 27 per cent, the calf from 9 to 10 per cent and the foot from 2.5 to 3 per cent of the total body volume.

6. By reducing the yearly increase in volume to the percentage of the volume of the preceding year, it was possible to show the relative rate of growth for the whole body and for each of the segments, thus showing the growth rhythms that are common to the group.

7. By the use of the foregoing method of showing the relative rate of growth at different ages, it was possible to show the growth lag

TABLE 42.—*The Thigh: Mean Volume and Mean Height in Percentage of Total Volume and Total Height*

Age	Settlement Group			University Group			All		
	No.	Volume	Height	No.	Volume	Height	No.	Volume	Height
5	..	....	....	1	23.6	18.1	1	23.6	18.1
6	2	26.3	19.9	..	....	....	2	26.3	19.9
7	1	29.1	20.4	..	....	....	1	29.1	20.4
8	1	25.8	21.8	..	....	....	1	25.8	21.8
9	3	24.8	22.6	..	....	....	3	24.8	22.6
10	5	23.4	21.4	1	22.9	21.6	6	23.3	21.4
11	8	22.4	23.8	2	25.2	23.6	10	24.5	23.1
12	7	25.2	23.2	10	26.8	23.4	17	26.0	23.2
13	14	25.6	23.6	13	25.9	24.0	27	25.8	23.8
14	10	26.0	23.3	22	25.6	23.6	32	25.7	23.5
15	18	27.3	23.3	19	26.8	23.8	37	27.1	23.5
16	..	....	....	17	26.0	23.2	17	26.0	23.2
17	..	....	....	8	27.1	24.2	8	27.1	24.2
18	..	....	....	1	27.0	22.2	1	27.0	22.2
19	..	....	....	1	23.9	21.8	1	23.9	21.8

in late childhood and the adolescent spurt that follows for the body as a whole and for all the segments with the exception of the cranium and the foot. That there are such a lag and such an adolescent spurt for the whole body can be shown from the weight norm of Baldwin (especially the norms for short boys and short girls) by subjecting it to the same treatment as used here, namely, taking the increase between any two years and reducing it to the percentage of the weight of the preceding year, although these same norms have been used by Bigelow as evidence to show that there is no year of unusual increase in the rate of growth which could be called an adolescent spurt. Of the three major segments, the leg is first to reach the low level and start the adolescent spurt at about 10 years of age, increasing to 12, and remaining high until after 16. The head segment begins its increase at about 11 years of age, increasing to 13 and dropping rapidly thereafter. The trunk begins its increase about 12 and continues to increase until about 16; then it drops rapidly.

SIGNIFICANCE

This study is significant in that it opens up an entirely new field by presenting a new method of studying physical growth. It makes possible the location of lags and spurts in growth for each of the segments in an individual or for a whole group. The chief value of the method will probably come when measurements have been made on the same subjects throughout their period of growth.

Although the method is of unquestionable value as a research device in physical growth, it is believed to be of great value in school health

TABLE 43.—*The Calf: Mean Volume and Mean Height of All Boys Measured by Water Displacement*

Age	Settlement Group			University Group			All		
	No.	Volume	Height	No.	Volume	Height	No.	Volume	Height
	Measurements in Cubic Inches and Inches								
5	..	...	....	1	110	10.0	1	110	10.0
6	2	145	11.2	..	...	....	2	145	11.2
7	1	130	12.0	..	...	....	1	130	12.0
8	1	140	11.8	..	...	....	1	140	11.8
9	3	168	12.0	..	...	....	3	168	12.0
10	5	166	12.3	1	200	13.0	6	172	12.4
11	8	171	12.9	2	188	13.6	10	174	13.0
12	7	204	13.2	10	212	14.0	17	209	13.7
13	14	211	14.0	13	236	14.9	27	223	14.4
14	10	222	14.2	22	278	15.0	32	265	14.8
15	18	236	14.1	19	299	15.7	37	270	14.9
16	..	...	....	17	314	15.8	17	314	15.8
17	..	...	....	8	333	16.6	8	333	16.6
18	..	...	....	1	315	16.5	1	315	16.5
19	..	...	....	1	280	13.8	1	280	13.8
	Measurements in Cubic Centimeters and Centimeters								
5	..	.....	....	1	1,801	25.4	1	1,801	25.4
6	2	2,375	28.4	..	.....	....	2	2,375	28.4
7	1	2,129	30.5	..	.....	....	1	2,129	30.5
8	1	2,293	29.9	..	.....	....	1	2,293	29.9
9	3	2,751	30.5	..	.....	....	3	2,751	30.5
10	5	2,718	31.3	1	3,275	33.0	6	2,817	31.8
11	8	2,800	32.8	2	3,079	34.5	10	2,850	33.0
12	7	3,340	33.5	10	3,471	35.6	17	3,422	34.8
13	14	3,455	35.6	13	3,865	37.9	27	3,652	36.6
14	10	3,636	36.1	22	4,552	38.1	32	4,339	37.6
15	18	3,865	35.9	19	4,896	39.9	37	4,422	38.9
16	..	.....	....	17	5,142	40.1	17	5,142	40.1
17	..	.....	....	8	5,453	42.1	8	5,453	42.1
18	..	.....	....	1	5,158	41.9	1	5,158	41.9
19	..	.....	....	1	4,586	35.0	1	4,586	35.0

work and other fields of education, such as swimming instruction. The measurement can be completed in about eight minutes. A comparison of the graphs made on the same subject at different times will show where and how extensive have been the changes in volume between the time of the two measurements.

The study is also significant in that it has shown the invalidity of formulas for body volume. Since the present method gives body volume accurately, any further need of such formulas is entirely eliminated.

The specific gravity of the whole body should be significant to swimming instructors in locating natural difficulties in learning to swim. It

may also have contributions to make in locating the onset of puberty or other physical changes.

The pointing out of the maximum height and the method of securing it at any time of the day or after any amount of exercise should be significant.

The growth lag and adolescent spurt in the various segments should be of special significance in modifying educational procedure at the ages influenced.

LIMITATIONS

A number of limitations are apparent in this study, chief among which are the following:

1. Only boys were studied, and no sex differences are shown.

TABLE 44.—*The Calf: Mean Volume and Mean Height in Percentage of Total Volume and Total Height*

Age	Settlement Group			University Group			All		
	No.	Volume	Height	No.	Volume	Height	No.	Volume	Height
5	..	....	....	1	8.7	22.6	1	8.7	22.6
6	2	11.9	23.1	..	....	....	2	11.9	23.1
7	1	8.4	24.0	..	....	....	1	8.4	24.0
8	1	9.0	23.7	..	....	....	1	9.0	23.7
9	3	10.0	23.1	..	....	....	3	10.0	23.1
10	5	9.3	22.8	1	7.8	22.0	6	9.1	22.8
11	8	9.4	22.9	2	9.8	24.1	10	9.5	23.1
12	7	9.2	23.2	10	8.8	23.3	17	9.0	23.2
13	14	9.9	23.8	13	9.2	23.8	27	9.6	23.8
14	10	8.9	23.4	22	9.8	23.5	32	9.5	23.5
15	18	8.8	22.8	19	9.1	23.3	37	8.9	23.1
16	..	...	....	17	9.3	23.0	17	9.3	23.0
17	..	...	....	8	9.3	23.5	8	9.3	23.5
18	..	...	....	1	7.9	22.5	1	7.9	22.5
19	..	...	....	1	8.5	21.2	1	8.5	21.2

2. No pure racial groups were studied, and no racial differences could be shown.

3. The limitation of time prevented the making of successive measurements on the same subjects, so that no individual growth rhythms or lags and spurts could be shown.

4. Certain errors in the measurements have been pointed out, such as the effect of breathing on the upper segments and variation in location of the division points between the segments.

POSSIBLE IMPROVEMENT AND EXTENSION OF THE METHOD

Certain improvements and extension of the method became apparent as the study progressed, chief among which are the following:

1. The accuracy of the apparatus could be improved by increasing the length and diminishing the cross-section of the tubes in which the displaced water is measured. The size of the graph used in this study

allowed readings to the nearest 5 cubic inches on the cumulative graph and to the nearest cubic inch on the profile graph.

2. Consecutive measurements on the same subjects should be made throughout their period of growth in order to locate the growth rhythms of the segments and to determine their connection with the development of the individual.

3. An apparatus somewhat similar to the one used in this study, in which the subject stands on a platform supported by buoyancy tanks,

TABLE 45.—*The Foot: Mean Volume and Mean Height of All Boys Measured by Water Displacement*

Age	Settlement Group			University Group			All		
	No.	Volume	Height	No.	Volume	Height	No.	Volume	Height
	Measurements in Cubic Inches and Inches								
5	..	..	...	1	21	2.0	1	21	2.0
6	2	35	1.9	..	..	...	2	35	1.9
7	1	42	2.0	..	..	...	1	42	2.0
8	1	46	2.2	..	..	...	1	46	2.2
9	3	52	2.8	..	..	...	3	52	2.8
10	5	51	2.6	1	65	2.8	6	54	2.6
11	8	60	2.6	2	52	2.5	10	58	2.6
12	7	61	2.8	10	68	2.8	17	65	2.8
13	14	70	2.8	13	74	2.9	27	72	2.8
14	10	71	2.9	22	78	2.9	32	76	2.9
15	18	77	2.9	19	87	3.0	37	82	2.9
16	..	..	...	17	95	3.0	17	95	3.0
17	..	..	...	8	98	3.1	8	98	3.1
18	..	..	...	1	85	3.0	1	85	3.0
19	..	..	...	1	70	3.2	1	70	3.2
	Measurements in Cubic Centimeters and Centimeters								
5	..	...	...	1	344	5.1	1	344	5.1
6	2	573	4.8	..	...	...	2	573	4.8
7	1	688	5.1	..	...	...	1	688	5.1
8	1	753	5.6	..	...	...	1	753	5.6
9	3	852	7.1	..	...	...	3	852	7.1
10	5	835	6.6	1	1,065	7.1	6	884	6.7
11	8	983	6.6	2	852	6.4	10	950	6.6
12	7	999	7.1	10	1,114	7.1	17	1,065	7.1
13	14	1,146	7.1	13	1,212	7.4	27	1,179	7.1
14	10	1,163	7.4	22	1,277	7.4	32	1,245	7.4
15	18	1,261	7.4	19	1,425	7.6	37	1,343	7.5
16	..	...	...	17	1,556	7.6	17	1,556	7.6
17	..	...	...	8	1,605	7.9	8	1,605	7.9
18	..	...	...	1	1,392	7.6	1	1,392	7.6
19	..	...	...	1	1,146	8.1	1	1,146	8.1

would enable the specific gravity of the segments to be determined. Knowledge of the volume and the specific gravity of the segment would make it possible to determine the weight of the segment, thus obtaining the weight of the head or any other part of the body. As this study has shown that there is a great difference in the specific gravity of individuals, so would this further study be able to show the difference in the specific gravity and weight of the different segments of the same individual and the variations from age to age.

THE SPECIFIC GRAVITY APPARATUS

The apparatus for measuring the specific gravity of the body segments is designed to be used in connection with the apparatus for

measuring the volume of the segments. A measurement on the specific gravity apparatus alone would be meaningless, but after having measured a subject in each apparatus and having made records on the same graph, it is possible to secure the length, volume, specific gravity and weight of any segment of the body as defined by two horizontal planes. The specific gravity apparatus, unlike the volume apparatus, is not confined to a small tank, but is set up at the side of a swimming tank or other large tank of water. It may be located in a room adjoining a large tank of water and have surface or underwater connection with the large tank. This installation in or connection with the large tank is necessary from the fact that when a segment in which the specific gravity is less or greater than the specific gravity of water is lowered into the water, a rise or fall in the surface of the water

TABLE 46.—*The Foot: Mean Volume and Mean Height in Percentage of Total Volume and Total Height*

Age	Settlement Group			University Group			All		
	No.	Volume	Height	No.	Volume	Height	No.	Volume	Height
5	..	...	...	1	1.7	4.5	1	1.7	4.5
6	2	2.9	3.9	..	...	...	2	2.9	3.9
7	1	2.7	4.0	..	...	...	1	2.7	4.0
8	1	3.0	4.5	..	...	...	1	3.0	4.5
9	3	3.1	4.9	..	...	...	3	3.1	4.9
10	5	2.9	4.7	1	2.5	4.7	6	2.8	4.7
11	8	3.3	4.6	2	2.7	4.4	10	3.2	4.5
12	7	2.8	4.9	10	2.9	4.6	17	2.8	4.7
13	14	3.3	4.7	13	2.9	4.6	27	3.1	4.6
14	10	2.9	4.7	22	2.7	4.6	32	2.8	4.6
15	18	2.9	4.8	19	2.7	4.4	37	2.8	4.6
16	..	...	...	17	2.8	4.4	17	2.8	4.4
17	..	...	...	8	2.8	4.4	8	2.8	4.4
18	..	...	...	1	2.1	4.1	1	2.1	4.1
19	..	...	...	1	2.1	4.9	1	2.1	4.9

would result if confined to a very small tank, but in or connected with the large tank the rise or fall becomes infinitely small.

The specific gravity apparatus appears as in figure 30, and consists of a number of hollow buoyancy tanks securely fastened together and able to move freely up and down in guides secured to the bottom and sides of the tank but with little or no lateral movement. Extending upward from the four corners of the buoyancy tanks is a framework of angle iron for the support of the lowering device and the platform on which the subject stands while being lowered into the water while the measurement is being made.

The Buoyancy Tanks.—The buoyancy tanks or tubes are made of drawn brass and are about 8 feet (243.8 cm.) in length with an outside diameter of 6 inches (15.2 cm.). These tubes are hollow and closed at both ends to prevent the entrance of additional material. A number of supplementary tubes of the same length but of various diameters are

used in adjusting the apparatus. It is preferable to use these small tubes rather than a larger tank on each side as the water pressure is not sufficient to press the walls of the tubes inward and thus vary their buoyancy.

The Superstructure.—Extending upward from the top of the buoyancy tanks at each of the four corners are angle iron supports about 7 feet in length. These are securely fastened together at the

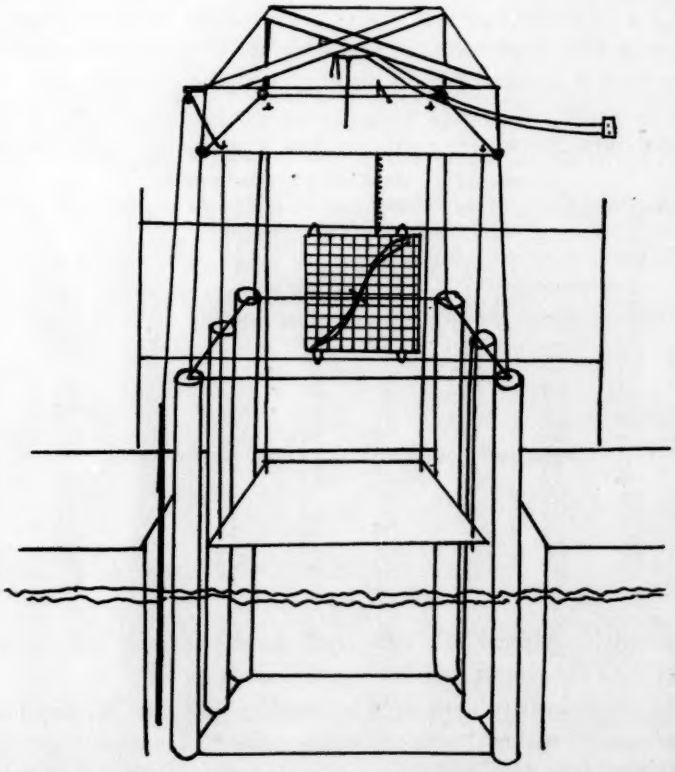

Fig. 30.—Apparatus for measuring the specific gravity of the segments of the human body.

top by a steel frame from the center of which is suspended an electric hoist actuated by a wall control. The wires that connect the wall control to the electric hoist are of sufficient length to allow free movement up and down without changing the weight or tension on the superstructure. On the drum of the hoist is a quarter inch copper cable which is fastened to the center of the upper frame that supports the platform on which the subject stands. This platform is supported by four half inch rods, extending from the upper frame to the platform.

The Compensating Devices.—In the operation of the apparatus, two compensating devices are necessary. To compensate for the four half inch rods, which are lowered into the water as the subject is lowered, is a compensating rod 1 inch in diameter of the same material as the four supporting rods and so adjusted that it is raised or lowered the same amount as the supporting rods, but in the opposite direction. This rod is suspended on a piano wire which runs over a pully attached to the top of the frame. When the compensation is exact, there is no change

TABLE 47.—*The Total Leg: Mean Volume and Mean Length for All the Boys. Measured by Water Displacement*

Age	Settlement Group			University Group			All		
	No.	Volume	Height	No.	Volume	Height	No.	Volume	Height
	Measurements in Cubic Inches and Inches								
5	..	...	....	1	430	20.0	1	430	20.0
6	2	500	22.8	..	...	....	2	500	22.8
7	1	620	24.2	..	...	....	1	620	24.2
8	1	590	24.5	..	...	....	1	590	24.5
9	3	638	26.4	..	...	....	3	638	26.4
10	5	634	26.7	1	850	28.5	6	670	27.0
11	8	677	28.3	2	725	29.3	10	685	28.5
12	7	820	28.9	10	920	30.7	17	879	30.0
13	14	821	30.5	13	980	32.7	27	901	31.6
14	10	947	31.3	22	1,108	33.1	32	1,058	32.5
15	18	1,051	31.4	19	1,245	34.4	37	1,151	33.1
16	..	.....	....	17	1,295	34.7	17	1,295	34.7
17	..	.....	....	8	1,403	36.8	8	1,403	36.8
18	..	.....	....	1	1,480	35.8	1	1,480	35.8
19	..	.....	....	1	1,140	31.2	1	1,140	31.2
	Measurements in Cubic Centimeters and Centimeters								
5	..	.....	....	1	7,042	50.8	1	7,042	50.8
6	2	8,189	57.9	..	.....	....	2	8,189	57.9
7	1	10,154	61.5	..	.....	....	1	10,154	61.5
8	1	9,662	62.3	..	.....	....	1	9,662	62.3
9	3	10,448	67.0	..	.....	....	3	10,448	67.0
10	5	10,383	67.8	1	13,920	72.4	6	10,973	68.6
11	8	11,088	71.9	2	11,873	75.0	10	11,218	72.4
12	7	13,429	73.4	10	15,067	78.0	17	14,396	76.2
13	14	13,445	77.5	13	16,049	83.1	27	14,775	80.2
14	10	15,509	79.5	22	18,145	84.1	32	17,326	82.6
15	18	17,211	79.7	19	20,389	87.4	37	18,850	84.1
16	..	.....	....	17	21,208	88.2	17	21,208	88.2
17	..	.....	....	8	22,977	93.4	8	22,977	93.4
18	..	.....	....	1	24,238	90.9	1	24,238	90.9
19	..	.....	....	1	18,670	79.2	1	18,670	79.2

in the height of the buoyancy tanks above the surface of the water when the platform is raised or lowered without a subject on it. To compensate for the weight added to the superstructure as the buoyancy tanks rise when a subject is being measured, another compensating rod is necessary. This rod must be such that 1 inch cross-section of the rod weighs the same as 1 inch cross-section of the combined buoyancy tubes. This rod is supported by a piano wire, the other end of which is fastened to the buoyancy tubes while the wire runs over a pully attached to the ceiling of the room. Thus this rod is lowered the same amount as the buoyancy tanks rise.

The Graph Board.—Secured to the wall or other rigid support near the buoyancy tanks is a graph board about 16 by 24 inches (40.6 by 60.9 cm.). This board is controlled in the same manner as the graph board used in the apparatus for measuring volume. It moves to the left one fifth of an inch for each inch the subject is lowered. The pen that traces the graph is mounted on a rod with an extension sleeve that is fastened to the buoyancy tanks, so that the pen can be set at the zero line at the beginning of the measurement.

Adjustment of the Apparatus.—By varying the number and size of the buoyancy tubes, the apparatus is adjusted so that the buoyancy tubes will rise 1 inch for every 200 cubic inches of material of the density of water that is lowered into the water and its weight released from the support of the buoyancy tubes. This allows the same graph to

TABLE 48.—*The Total Leg: Mean Volume and Mean Height in Percentage of Total Volume and Total Height*

Age	Settlement Group			University Group			All		
	No.	Volume	Height	No.	Volume	Height	No.	Volume	Height
5	..	....	....	1	34.0	45.3	1	34.0	45.3
6	2	41.1	47.0	..	....	....	2	41.1	47.0
7	1	40.3	48.4	..	....	....	1	40.3	48.4
8	1	37.8	50.0	..	....	....	1	37.8	50.0
9	3	37.9	50.6	..	....	....	3	37.9	50.6
10	5	35.6	48.5	1	33.2	48.3	6	35.2	48.4
11	8	36.9	50.1	2	37.8	52.1	10	37.1	50.5
12	7	37.2	50.6	10	38.5	51.3	17	37.9	51.0
13	14	38.8	52.1	13	37.9	52.5	27	38.4	52.3
14	10	37.8	51.5	22	39.0	51.6	32	38.6	51.5
15	18	39.0	50.9	19	38.6	51.6	37	38.8	51.2
16	..	....	....	17	38.1	50.6	17	38.1	50.6
17	..	....	....	8	39.2	52.1	8	39.2	52.1
18	..	....	....	1	37.0	48.8	1	37.0	48.8
19	..	....	....	1	34.5	48.0	1	34.5	48.0

be used as was used to measure the volume of the segments in which the volume curve rose 1 inch for every 200 cubic inches of water displaced. If 200 cubic inches of material with a density twice that of water is lowered, it would lose only the weight of an equal volume of water, and the buoyancy tanks would rise only one half inch instead of 1 inch. If material with three times the density of water is lowered, the buoyancy tanks rise only one third of an inch instead of 1 inch. Thus the vertical rise of the volume graph divided by the vertical rise in the specific gravity curve will always give the specific gravity of the segment. Thus when the specific gravity of the material lowered is equal to that of water, 1 inch divided by 1 inch, or a specific gravity of 1.00, is obtained. When the specific gravity is twice that of water, 1 inch divided by one-half inch, or 2.00, is obtained. When the specific gravity is three times that of water, 1 inch divided by one-third inch, or a specific gravity of 3.00, is obtained.

Making the Measurement.—To make a measurement in the specific gravity apparatus, the subject steps on the platform, which has been raised some distance above the surface of the water. The subject's weight forces the apparatus down until equilibrium is established, that is, until the combined weight of the subject and the upper part of the apparatus are exactly equal to the weight of the water displaced. The platform is then adjusted so that the top surface of the platform is just at the surface of the water. The graph on which the volume of the subject has been recorded is adjusted to the graph board and

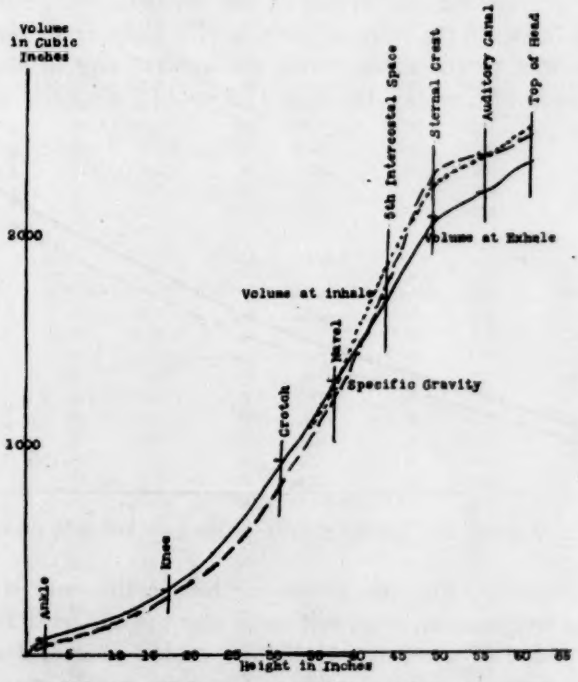

Fig. 31.—Volume and specific gravity curves.

the pen raised or lowered so that it stands on the zero point at the bottom and the left of the graph board. The subject can be lowered rapidly as it is not necessary to wait on the overflow of water as when measuring for volume. After adjustment, the measure can be made in about one minute as compared with eight or ten minutes needed to measure the volume. A tube is provided through which the subject can breathe while the head is submerged, but the measurement is made so rapidly that this is not necessary except in the case of very young subjects.

The Graphs Made.—When a subject has been measured in the volume apparatus and in the specific gravity apparatus and the graph

recorded on the same sheet of graph paper, it would appear as in figure 31. When the specific gravity of the subject is less than that of water, the specific gravity curve does not rise as rapidly as the volume curve, since the part submerged loses only the weight of an equal volume of water, and the weight not lost remains on the buoyancy tanks and prevents their rising as high as they would if the specific gravity was the same as that of water.

Computations.—By transferring a part of the graph given in figure 31 to a larger scale, as given in figure 32, the computation of the specific gravity and the weight of any segment can be illustrated. The vertical raise of the volume curve is 17.5 units from zero, or the sole of the foot to the ankle, while the vertical rise of the specific gravity curve is 13.5 units. Dividing 17.5 by 13.5 a specific gravity of

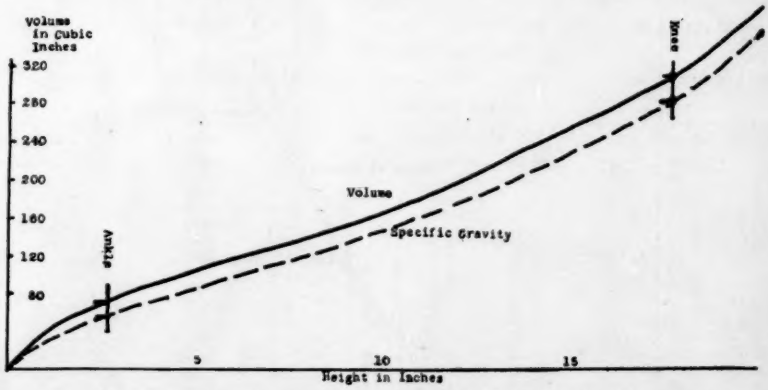

Fig. 32.—Volume and specific gravity of the foot and calf segments.

1.29— is obtained. The volume of the feet in this case is 70 cubic inches. The weight of an equal volume of water would be 70 times 0.578 ounces (1 pound of water equals 27.6923 cubic inches or 1 cubic inch equals 0.578 ounces) or 40.46 ounces. Since the specific gravity of this segment is 1.29, the weight would be 1.29 times 40.46 ounces, or 52.1934 ounces. Both feet weigh 3 pounds, 4.1934 ounces, or one foot weighs 1 pound, 10.0967 ounces.

At the knee, the curve for volume has raised 77.5 units, while the curve for specific gravity has raised 71.0 units, or the specific gravity of the foot and calf segments combined is 77.5 divided by 71.0, or 1.09 +. The volume to the knee is 310 cubic inches, and the weight of an equal volume of water is 310 times 0.578 ounces, or 179.18 ounces. Since the specific gravity of the segments is 1.09, the weight of the two segments would be 1.09 times 179.18 ounces, or 195.3062 ounces. If the volume of the foot segment already found is

Metric Equivalents of English Units

Units of Length

Inch	Cm.	Inch	Cm.	Inch	Cm.	Inch	Cm.	Inch	Cm.
1	2.5	17	43.2	33	83.8	49	124.5	65	165.1
2	5.1	18	45.7	34	86.4	50	127.0	66	167.6
3	7.6	19	48.3	35	88.9	51	129.5	67	170.2
4	10.2	20	50.8	36	91.4	52	132.1	68	172.7
5	12.7	21	53.3	37	94.0	53	134.6	69	175.3
6	15.2	22	55.9	38	96.5	54	137.2	70	177.8
7	17.8	23	58.4	39	99.1	55	139.7	71	180.3
8	20.3	24	61.0	40	101.6	56	142.2	72	182.9
9	22.9	25	63.5	41	104.1	57	144.8	73	185.4
10	25.4	26	66.0	42	106.7	58	147.3	74	188.0
11	27.9	27	68.6	43	109.2	59	149.9	75	190.5
12	30.5	28	71.1	44	111.8	60	152.4	76	193.0
13	33.0	29	73.7	45	114.3	61	154.9	77	195.6
14	35.6	30	76.2	46	116.8	62	157.5	78	198.1
15	38.1	31	78.7	47	119.4	63	160.0	79	200.7
16	40.6	32	81.3	48	121.9	64	162.6	80	203.2

Units of Weight

Pounds	Kilos	Pounds	Kilos	Pounds	Kilos	Pounds	Kilos	Pounds	Kilos
1	0.5	31	14.1	61	27.7	91	41.3	121	54.9
2	0.9	32	14.5	62	28.1	92	41.8	122	55.4
3	1.4	33	15.0	63	28.6	93	42.2	123	55.8
4	1.8	34	15.4	64	29.0	94	42.7	124	56.3
5	2.3	35	15.9	65	29.5	95	43.1	125	56.7
6	2.7	36	16.3	66	29.9	96	43.6	126	57.1
7	3.2	37	16.8	67	30.4	97	44.0	127	57.6
8	3.6	38	17.3	68	30.8	98	44.5	128	58.1
9	4.1	39	17.7	69	31.3	99	44.9	129	58.5
10	4.5	40	18.1	70	31.8	100	45.4	130	59.0
11	5.0	41	18.6	71	32.2	101	45.8	131	59.4
12	5.4	42	19.1	72	32.7	102	46.3	132	59.9
13	5.9	43	19.5	73	33.1	103	46.8	133	60.3
14	6.4	44	20.0	74	33.6	104	47.2	134	60.8
15	6.8	45	20.4	75	34.0	105	47.7	135	61.3
16	7.3	46	20.9	76	34.5	106	48.1	136	61.7
17	7.7	47	21.3	77	35.0	107	48.6	137	62.2
18	8.2	48	21.8	78	35.4	108	49.0	138	62.6
19	8.6	49	22.2	79	35.9	109	49.5	139	63.1
20	9.1	50	22.7	80	36.3	110	49.9	140	63.5
21	9.5	51	23.1	81	36.8	111	50.4	141	64.0
22	10.0	52	23.6	82	37.2	112	50.8	142	64.4
23	10.4	53	24.0	83	37.7	113	51.3	143	65.0
24	10.9	54	24.5	84	38.1	114	51.7	144	65.4
25	11.3	55	25.0	85	38.6	115	52.2	145	65.9
26	11.8	56	25.4	86	39.0	116	52.7	146	66.4
27	12.3	57	25.9	87	39.5	117	53.1	147	66.8
28	12.7	58	26.3	88	39.9	118	53.5	148	67.3
29	13.2	59	26.8	89	40.4	119	54.0	149	67.7
30	13.6	60	27.2	90	40.8	120	54.4	150	68.0

Metric Equivalent of English Units—Continued

Units of Volume

Cubic Inches	Cubic Centimeters	Cubic Inches	Cubic Centimeters	Cubic Inches	Cubic Centimeters	Cubic Inches	Cubic Centimeters
0.1	1.6377	41	671.457	90	1,473.93	139	2,276.403
0.2	3.2754	42	687.834	91	1,490.307	140	2,292.78
0.3	4.9131	43	704.211	92	1,506.684	141	2,309.157
0.4	6.5508	44	720.588	93	1,523.061	142	2,325.534
0.5	8.1885	45	735.965	94	1,539.438	143	2,341.911
0.6	9.8262	46	753.342	95	1,555.815	144	2,358.288
0.7	11.4639	47	769.719	96	1,572.192	145	2,374.665
0.8	13.1016	48	786.096	97	1,588.569	146	2,391.042
0.9	14.7393	49	802.473	98	1,604.946	147	2,407.419
1	16.377	50	818.85	99	1,621.323	148	2,423.796
2	32.754	51	835.227	100	1,637.7	149	2,440.173
3	49.131	52	851.604	101	1,654.077	150	2,456.55
4	65.508	53	867.981	102	1,670.454	151	2,472.927
5	81.885	54	884.358	103	1,686.831	152	2,489.304
6	98.262	55	900.735	104	1,703.208	153	2,505.681
7	114.639	56	917.112	105	1,719.585	154	2,522.058
8	131.016	57	933.489	106	1,735.962	155	2,538.435
9	147.393	58	949.866	107	1,752.339	156	2,554.812
10	163.77	59	966.243	108	1,768.716	157	2,571.189
11	180.147	60	982.62	109	1,785.093	158	2,587.566
12	196.524	61	998.997	110	1,801.47	159	2,603.943
13	212.901	62	1,015.374	111	1,817.847	160	2,620.32
14	229.278	63	1,031.751	112	1,834.224	161	2,636.697
15	245.655	64	1,048.128	113	1,850.601	162	2,653.074
16	262.032	65	1,064.505	114	1,866.978	163	2,669.451
17	278.409	66	1,080.882	115	1,883.355	164	2,685.828
18	294.786	67	1,097.259	116	1,899.732	165	2,702.205
19	311.163	68	1,113.636	117	1,916.109	166	2,718.582
20	327.54	69	1,130.013	118	1,932.486	167	2,734.959
21	343.917	70	1,146.39	119	1,948.863	168	2,751.336
22	360.294	71	1,162.767	120	1,965.24	169	2,767.713
23	376.671	72	1,179.144	121	1,981.617	170	2,784.09
24	393.048	73	1,195.521	122	1,997.994	171	2,800.467
25	409.425	74	1,211.898	123	2,014.371	172	2,816.844
26	425.802	75	1,228.275	124	2,030.748	173	2,833.221
27	442.179	76	1,244.652	125	2,047.125	174	2,849.598
28	458.556	77	1,261.029	126	2,063.502	175	2,865.975
29	474.933	78	1,277.406	127	2,079.879	176	2,882.352
30	491.31	79	1,293.783	128	2,096.256	177	2,898.729
31	507.687	80	1,310.16	129	2,112.633	178	2,915.106
32	524.064	81	1,326.537	130	2,129.01	179	2,931.483
33	540.441	82	1,342.914	131	2,145.387	180	2,947.86
34	556.818	83	1,359.291	132	2,161.764	181	2,964.237
35	573.195	84	1,375.668	133	2,178.141	182	2,980.614
36	589.572	85	1,392.045	134	2,194.518	183	2,996.991
37	605.949	86	1,408.422	135	2,210.895	184	3,013.368
38	622.326	87	1,424.799	136	2,227.272	185	3,029.745
39	638.703	88	1,441.176	137	2,243.649	186	3,046.122
40	655.08	89	1,457.553	138	2,260.026	187	3,062.499

Metric Equivalent of English Units—Continued

Cubic Inches	Cubic Centimeters	Cubic Inches	Cubic Centimeters	Cubic Inches	Cubic Centimeters	Cubic Inches	Cubic Centimeters	Cubic Inches	Cubic Centimeters
188	3,079	240	3,930	293	4,798	346	5,666	399	6,534
189	3,095	241	3,947	294	4,815	347	5,683	400	6,551
190	3,112	242	3,963	295	4,831	348	5,699	401	6,568
191	3,128	243	3,979	296	4,847	349	5,715	402	6,584
192	3,144	244	3,996	297	4,864	350	5,732	403	6,600
193	3,161	245	4,012	298	4,880	351	5,748	404	6,617
194	3,177	246	4,028	299	4,896	352	5,764	405	6,633
195	3,193	247	4,045	300	4,913	353	5,781	406	6,649
196	3,210	248	4,061	301	4,929	354	5,797	407	6,666
197	3,226	249	4,077	302	4,945	355	5,813	408	6,682
198	3,242	250	4,094	303	4,964	356	5,830	409	6,698
199	3,259	251	4,110	304	4,980	357	5,846	410	6,715
200	3,275	252	3,126	305	4,996	358	5,862	411	6,731
201	3,291	253	4,143	306	5,013	359	5,879	412	6,747
202	3,307	254	4,160	307	5,029	360	5,896	413	6,764
203	3,323	255	4,176	308	5,044	361	5,912	414	6,780
204	3,340	256	4,192	309	5,060	362	5,928	415	6,796
205	3,356	257	4,209	310	5,077	363	5,945	416	6,813
206	3,372	258	4,225	311	5,093	364	5,961	417	6,829
207	3,389	259	4,241	312	5,109	365	5,977	418	6,845
208	3,405	260	4,258	313	5,126	366	5,994	419	6,861
209	3,422	261	4,274	314	5,142	367	6,010	420	6,878
210	3,439	262	4,290	315	5,158	368	6,026	421	6,894
211	3,455	263	4,307	316	5,175	369	6,043	422	6,910
212	3,471	264	4,323	317	5,191	370	6,059	423	6,927
213	3,488	265	4,339	318	5,207	371	6,075	424	6,943
214	3,504	266	4,356	319	5,224	372	6,092	425	6,959
215	3,520	267	4,372	320	5,241	373	6,108	426	6,976
216	3,537	268	4,388	321	5,257	374	6,124	427	6,992
217	3,553	269	4,405	322	5,273	375	6,141	428	7,008
218	3,569	270	4,422	323	5,290	376	6,157	429	7,025
219	3,586	271	4,438	324	5,306	377	6,173	430	7,042
220	3,603	272	4,454	325	5,322	378	6,190	431	7,058
221	3,619	273	4,471	326	5,339	379	6,206	432	7,074
222	3,636	274	4,487	327	5,355	380	6,223	433	7,091
223	3,652	275	4,503	328	5,371	381	6,239	434	7,107
224	3,668	276	4,520	329	5,388	382	6,256	435	7,123
225	3,685	277	4,536	330	5,404	383	6,272	436	7,140
226	3,701	278	4,552	331	5,420	384	6,288	437	7,156
227	3,717	279	4,569	332	5,437	385	6,304	438	7,172
228	3,734	280	4,586	333	5,453	386	6,321	439	7,189
229	3,750	281	4,602	334	5,469	387	6,338	440	7,206
230	3,767	282	4,618	335	5,486	388	6,354	441	7,222
231	3,783	283	4,635	336	5,502	389	6,370	442	7,238
232	3,800	284	4,651	337	5,518	390	6,387	443	7,255
233	3,816	285	4,667	338	5,535	391	6,403	444	7,271
234	3,832	286	4,684	339	5,551	292	6,420	445	7,287
235	3,849	287	4,700	340	5,568	393	6,436	446	7,303
236	3,865	288	4,716	341	5,585	394	6,452	447	7,320
237	3,881	289	4,733	342	5,601	395	6,469	448	7,336
238	3,898	290	4,749	343	5,618	396	6,485	449	7,353
239	3,914	291	4,765	344	5,634	397	6,501	450	7,370
240	3,930	292	4,782	345	5,650	398	6,518	451	7,386

TABLE 49.—*Data and Detailed Measurements of One Hundred and Sixty-Four Boys Measured by Water Displacement* *

* Key to Table.—In this table, boys of the university group have numbers less than 100. Boys of the settlement group have numbers 100 or over. The following key is explanatory of the "Item Numbers" appearing at the top of the columns.

1. Case number instead of name of subject (see foregoing statements).
2. Age: year plus or minus number of days.
3. Standing height in air to nearest tenth of an inch.
4. Increase in height when measured in water.
5. Sitting height to nearest tenth of an inch.
6. Weight, stripped, to nearest tenth of a pound.
7. Specific gravity at full inhale.
8. Specific gravity at full exhale.
9. Width of chest to nearest tenth of an inch.
10. Depth of chest to nearest tenth of an inch.
11. Lung capacity to nearest cubic inch.
12. Volume of arms to nearest cubic inch.
13. Variation of Mumford's formula from actual volume.
14. Variation of Pirquet's formula from actual volume.
15. Volume of the foot to nearest cubic inch.
16. Volume of the foot in percentage of total volume.
17. Height of foot to nearest tenth of an inch.
18. Height of foot in percentage of total height in water.
19. Volume of the calf to nearest cubic inch.
20. Volume of calf in percentage of total volume.
21. Height of calf to nearest tenth of an inch.
22. Height of calf in percentage of total height.
23. Volume of thigh to nearest cubic inch.
24. Volume of thigh in percentage of total volume.
25. Height of thigh to nearest tenth of an inch.
26. Height of thigh in percentage of total height.
27. Volume of total leg to nearest cubic inch.
28. Volume of total leg in percentage of total volume.
29 Height of total leg to nearest tenth of an inch.
30. Height of total leg in percentage of total height.

			Item Number																										
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1	5 0	43.6	0.6	23.0	47.0	0.973	1.028	7.0	5.0	73	87	—32	—48	21	1.7	2.0	4.5	110	8.7	10.0	22.6	299	23.6	8.0	18.1	430	34.0	20.0	45.3
101	6 —10	47.5	0.3	25.0	45.0	0.987	1.039	6.0	4.0	63	127	—267	363	30	2.5	1.8	3.8	130	10.8	11.2	23.4	360	30.0	9.5	19.9	520	43.3	22.5	47.1
102	6 +14	48.5	0.5	24.8	46.0	0.980	1.027	5.8	4.2	58	108	—288	276	40	3.2	2.0	4.1	160	12.9	11.2	22.9	280	22.6	9.8	20.0	480	38.7	23.0	46.9
Mean	6 +2	48.0	0.4	24.9	45.5	0.984	1.033	5.9	4.1	61	118	—278	320	35	2.9	1.9	3.9	145	11.9	11.2	23.1	320	26.3	9.7	19.9	500	41.0	22.8	47.0
103	7 +2	49.5	0.5	27.0	57.0	0.981	1.025	6.0	4.5	71	119	—489	428	42	2.7	2.0	4.0	130	8.4	12.0	24.0	448	29.1	10.2	20.4	620	40.3	24.2	48.4
104	8 +7	48.5	0.5	26.3	58.3	0.983	1.035	7.0	6.0	82	123	49	359	46	3.0	2.2	4.5	140	8.0	11.6	24.1	404	25.9	10.7	21.8	590	37.8	24.5	50.0
105	9 —42	51.8	0.4	27.2	63.9	0.983	1.047	7.2	5.2	110	138	—127	322	58	3.4	2.4	4.6	177	10.7	12.1	23.2	455	26.9	12.3	23.6	690	40.8	26.8	51.3
106	9 —15	51.0	0.4	27.2	63.7	0.988	1.037	6.5	4.2	84	115	—420	312	42	2.5	2.8	5.5	168	9.9	11.5	22.4	415	24.4	10.7	20.8	625	36.8	25.0	48.6
107	9 +30	52.0	0.5	27.0	62.5	0.978	1.043	7.0	5.5	110	134	—90	308	55	3.3	2.5	4.8	160	9.6	12.5	23.8	385	23.2	12.3	23.4	600	36.1	27.3	52.0
Mean	9 —9	51.6	0.43	27.1	63.4	0.983	1.042	6.9	4.96	101	129	—212	314	52	3.1	2.6	4.9	168	10.0	12.0	23.1	418	24.8	11.8	22.6	638	37.9	26.4	50.7
108	10 —27	53.0	0.4	27.5	68.0	0.974	1.04	7.8	6.2	134	173	240	280	57	3.2	2.6	4.9	163	9.1	12.3	23.0	440	24.4	11.6	21.7	660	36.7	26.5	49.6
109	10 —25	53.2	0.6	27.2	60.2	0.986	1.038	7.0	4.3	81	117	—300	402	50	3.1	2.7	5.0	170	10.6	11.6	21.6	375	23.3	11.7	21.8	595	37.0	26.0	48.3
110	10 —17	56.5	0.5	28.5	65.1	0.986	1.024	6.2	4.8	69	121	—370	565	55	3.1	2.8	4.9	155	8.8	12.5	21.9	395	22.4	12.0	21.1	605	34.4	27.3	48.0
111	10 —12	55.8	0.2	29.0	62.2	0.989	1.025	6.0	4.2	61	114	—540	759	38	2.3	2.5	4.5	130	7.7	13.0	23.2	382	22.7	12.0	21.4	550	32.7	27.5	49.1
112	10 +20	54.5	0.5	29.7	76.0	0.966	1.032	7.5	5.5	138	177	—232	580	57	2.8	2.4	4.4	213	10.4	12.0	21.8	490	24.0	11.6	21.1	760	37.3	26.0	47.3
Mean	10 —12	54.6	0.44	28.4	66.3	0.980	1.033	6.9	5.0	97	140	—241	517	51	2.9	2.6	4.7	166	9.3	12.3	22.8	416	23.4	11.8	21.4	634	35.6	26.7	48.5
2	10 +24	58.2	0.7	30.0	96.0	0.978	1.039	9.0	6.0	158	210	11	140	65	2.5	2.8	4.7	200	7.8	13.0	22.0	585	22.9	12.8	21.6	850	33.2	28.5	48.3
Mean	10 —6	55.2	0.5	28.7	71.3	0.980	1.036	7.25	5.2	107	152	—199	454	54	2.8	2.6	4.7	172	9.1	12.4	22.8	445	23.3	12.0	21.4	670	35.2	27.0	48.4
113	11 —30	54.6	0.4	29.0	54.5	1.003	1.040	5.4	4.2	54	81	—462	989	45	3.1	2.5	4.6	160	11.0	12.3	22.4	355	24.5	12.2	22.2	560	38.6	27.0	49.1
114	11 —15	58.6	0.4	31.4	81.0	0.979	1.044	8.5	7.0	141	190	650	942	65	3.0	2.7	4.6	175	8.1	13.8	23.4	550	25.6	13.5	22.9	790	36.7	30.0	50.9
115	11 —10	58.5	0.5	27.3	62.4	0.976	1.054	8.0	5.5	130	164	300	390	61	3.7	2.4	4.4	149	9.1	12.7	23.5	410	25.0	12.7	23.5	620	37.8	27.8	51.5
116	11 0	51.5	0.5	25.4	75.0	0.974	1.039	6.9	5.7	134	150	—395	—361	52	2.6	2.6	5.0	180	9.0	12.4	23.9	523	26.2	12.2	23.5	755	37.8	27.2	52.3
117	11 0	54.9	0.6	27.2	61.1	0.962	1.037	7.0	5.2	128	144	—26	382	63	3.9	2.5	4.5	142	8.7	13.3	24.0	460	28.2	13.2	23.8	665	40.8	29.0	52.3
118	11 +6	58.0	0.4	27.0	72.5	0.967	1.046	8.0	6.0	157	181	312	48	65	3.4	2.7	4.6	170	8.9	12.4	21.2	435	22.7	12.4	21.2	675	35.2	27.5	47.1
119	11 +19	62.8	0.2	33.0	72.8	0.965	1.040	8.6	6.0	148	166	688	1,636	62	3.2	2.6	4.1	198	10.2	13.8	21.9	385	19.9	14.2	22.5	645	33.3	30.6	48.6
120	11 +27	53.8	0.8	28.5	75.0	0.967	1.043	8.5	6.3	157	175	324	325	65	3.3	2.6	4.8	195	9.8	12.4	22.7	445	22.4	13.0	23.8	705	35.4	27.0	49.5
Mean	11 0	55.9	0.5	28.6	69.3	0.974	1.043	7.6	5.7	131	156	174	544	60	3.3	2.6	4.6	171	9.4	12.9	22.9	445	24.3	12.9	22.9	677	36.9	28.3	50.1
3	11 —30	56.5	0.7	28.3	65.0	0.943	1.020	7.5	5.0	143	162	—59	501	54	3.1	2.5	4.4	186	10.5	14.0	24.5	440	24.9	13.5	23.6	680	38.5	30.0	52.5
4	11 +114	55.9	0.1	28.0	79.2	0.977	1.054	9.5	6.0	163	196	591	115	50	2.4	2.5	4.5	190	9.1	13.3	23.8	530	25.5	13.2	23.6	770	37.0	29.0	51.8
Mean	11 +42	56.2	0.4	28.2	72.1	0.960	1.037	8.5	5.5	153	179	266	308	52	2.7	2.5	4.5	188	9.8	13.6	24.1	485	25.2	13.4	23.6	725	37.8	29.5	52.1
Mean	11 +8	56.0	0.46	28.5	69.9	0.971	1.042	7.8	5.7	136	161	192	497	58	3.2	2.6	4.5	175	9.5	13.0	23.1	453	24.5	13.0	23.1	687	37.1	28.5	50.5
121	12 —44	51.5	0.5	27.0	61.5	0.982	1.039	6.5	5.5	94	140	—184	328	45	2.7	2.4	4.6	150	9.2	12.0	23.1	370	22.6	11.1	21.4	565	34.5	25.5	49.0
122	12 —9	59.5	0.5	31.0	83.5	0.985	1.049	8.0	6.0	142	180	85	774	75	3.4	3.0	5.0	210	9.5	13.8	23.0	645	29.3	13.9	23.2	930	42.2	30.7	51.2
123	12 +2	57.5	0.5	30.0	74.0	0.964	1.054	6.0	4.5	99	138	—844	50	45	2.3	2.8	5.2	215	10.9	12.7	23.5	455	23.0	12.0	22.2	715	36.1	27.5	50.9
124	12 +7	59.5	0.5	31.5	85.4	1.004	1.054	7.5	6.0	138	201	262	365	65	2.6	2.6	4.5	225	9.0	13.4	23.0	640	25.6	14.0	24.0	930	37.2	29.0	49.7
125	12 +8	59.5	0.5	31.0	83.5	0.985	1.049	8.0	6.0	142	180	85	774	75	3.4	3.0	5.0	210	9.5	13.8	23.0	645	29.3	13.9	23.2	930	42.2	30.7	51.2
126	12 +8	59.5	0.5	31.0	83.5	0.985	1.049	8.0	6.0	142	180	85	774	75	3.4	3.0	5.0	210	9.5	13.8	23.0	645	29.3	13.9	23.2	930	42.2	30.7	51.2
127	12 +8	59.5	0.5	31.0	83.5	0.985	1.049	8.0	6.0	142	180	85	774	75	3.4	3.0	5.0	210	9.5	13.8	23.0	645	29.3	13.9	23.2	930	42.2	30.7	51.2
128	12 +8	59.5	0.5	31.0	83.5	0.985	1.049	8.0	6.0	142	180	85	774	75	3.4	3.0	5.0	210	9.5	13.8	23.0	645	29.3	13.9	23.2	930	42.2	30.7	51.2
129	12 +8	59.5	0.5	31.0	83.5	0.985	1.049	8.0	6.0	142	180	85	774	75	3.4	3.0	5.0	210	9.5	13.8	23.0	645	29.3	13.9	23.2	930	42.2	30.7	51.2
130	12 +8	59.5	0.5	31.0	83.5	0.985	1.049	8.0	6.0	142	180	85	774	75	3.4	3.0	5.0	210	9.5	13.8	23.0	645	29.3	13.9	23.2	930	42.2	30.7	51.2

Mean	11	+8	56.0	0.46	28.5	69.9	0.971	1.042	7.8	5.7	136	161	192	497	58	3.2	2.6	4.5	175	9.5	13.0	23.1	453	24.5	13.0	23.1	687	37.1	28.5	50.5

121	12	−44	51.5	0.5	27.0	61.5	0.982	1.039	6.5	5.5	94	140	−184	328	45	2.7	2.4	4.6	150	9.2	12.0	23.1	370	22.6	11.1	21.4	565	34.5	25.5	49.0
122	12	−9	59.5	0.5	31.0	83.5	0.985	1.049	8.0	6.0	142	180	85	774	75	3.4	3.0	5.0	210	9.5	13.8	23.0	645	29.3	13.9	23.2	930	43.2	30.7	51.2
123	12	0	53.5	0.5	27.3	75.4	1.004	1.054	6.0	4.5	99	138	−844	50	45	2.3	2.8	5.2	215	10.9	12.7	23.5	455	23.0	12.0	22.2	715	36.1	27.5	50.9
124	12	+17	58.0	0.4	30.6	95.0	0.986	1.052	7.9	6.0	166	204	−268	365	65	2.6	2.6	4.5	225	9.0	13.4	23.0	640	25.6	14.0	24.0	930	37.2	29.0	49.7
125	12	+20	56.5	0.5	29.4	77.2	0.989	1.047	8.2	5.8	119	162	134	501	68	3.3	2.9	5.1	192	9.4	13.3	23.3	505	24.8	12.8	22.5	765	37.5	29.0	50.9
126	12	+24	58.8	0.2	30.0	92.0	0.990	1.057	8.7	6.5	162	178	257	290	80	3.3	3.0	5.1	195	8.1	13.5	23.9	600	24.9	14.0	23.7	875	36.3	30.5	51.7
127	12	+61	59.0	0.6	31.0	100.0	0.984	1.049	9.2	7.0	174	212	400	339	52	2.0	2.9	4.9	243	9.2	13.8	23.2	665	25.2	13.8	23.2	960	36.4	30.5	51.2
Mean	12	+10	56.7	0.46	29.5	83.5	0.988	1.049	7.8	5.9	137	173	−60	378	61	2.8	2.8	4.9	204	9.2	13.2	23.1	554	25.0	13.1	22.9	820	37.2	28.9	50.6
5	12	−120	57.1	0.2	29.7	72.5	0.943	1.004	8.0	6.0	127	161	192	615	50	2.5	2.5	4.4	160	8.0	13.5	23.6	510	25.4	13.3	23.2	720	35.9	29.3	51.1
6	12	−89	56.6	0.2	29.7	82.0	0.982	1.051	8.2	6.0	153	172	81	460	65	3.0	2.6	4.6	175	8.1	12.4	21.8	590	27.3	13.5	23.8	830	38.4	28.5	50.2
7	12	+20	60.4	1.0	31.0	93.5	0.986	1.049	8.5	5.5	156	201	−146	509	75	3.0	2.8	4.6	205	8.3	14.8	24.1	690	27.9	14.4	23.5	970	39.3	32.0	52.1
8	12	+21	57.9	0.9	29.8	71.0	0.995	1.080	8.0	5.0	155	164	101	810	60	3.3	2.8	4.8	160	8.8	13.8	23.5	480	26.4	13.7	23.3	700	38.5	30.3	51.5
9	12	+22	60.0	0.7	31.5	98.0	0.987	1.052	8.0	6.0	168	203	−271	546	60	2.3	3.0	4.9	220	8.5	13.5	22.2	735	28.5	13.9	22.9	1,015	39.3	30.4	50.1
10	12	+22	55.0	0.6	28.2	77.0	0.986	1.055	8.5	5.5	142	190	97	223	55	2.7	2.5	4.5	160	7.9	12.5	22.5	525	26.0	13.0	23.4	740	36.6	28.0	50.4
11	12	+66	60.0	1.0	30.0	94.8	0.988	1.063	8.7	6.4	190	202	250	230	72	2.9	2.8	4.6	228	9.2	14.3	23.4	630	25.5	13.0	22.8	930	37.7	31.0	50.8
12	12	+121	61.0	0.2	30.7	91.6	0.992	1.066	9.0	5.3	175	188	102	513	70	2.9	2.6	4.3	240	10.1	15.0	24.5	620	26.1	14.1	23.0	930	39.1	31.7	51.8
13	12	+178	61.8	0.0	31.4	113.6	0.979	1.032	9.2	6.8	163	232	56	46	80	2.6	3.0	4.9	300	9.8	14.1	22.8	770	25.3	14.3	23.1	1,150	37.7	31.4	50.8
14	12	+180	64.0	0.4	32.2	109.6	0.997	1.049	9.5	6.8	154	219	490	449	90	3.1	3.0	4.7	270	9.3	15.9	24.7	855	29.4	15.8	24.5	1,215	42.0	34.7	53.9
Mean	12	+42	59.4	0.5	30.4	90.4	0.983	1.050	8.6	5.9	158	193	95	440	68	2.9	2.8	4.6	219	8.8	14.0	23.3	641	26.8	14.0	23.4	920	38.5	30.7	51.3
Mean	12	+29	58.2	0.5	30.0	87.5	0.985	1.050	8.2	5.9	149	185	31	415	65	2.8	2.8	4.7	213	9.0	13.7	23.2	605	26.0	13.6	23.2	879	37.9	30.0	51.0
128	13	−34	58.0	0.7	30.0	85.0	1.005	1.070	8.5	6.0	139	175	161	500	78	3.6	2.8	4.8	202	9.2	13.5	23.0	605	27.5	13.5	23.0	885	40.2	29.8	50.8
129	13	−21	53.5	0.5	28.0	78.0	0.988	1.059	8.2	5.8	147	184	19	155	55	2.7	2.5	4.6	225	11.0	12.5	23.2	485	23.8	12.0	22.2	765	37.5	27.0	50.0
130	13	−11	63.0	0.6	32.0	112.0	0.978	1.047	8.5	6.0	210	240	−395	317	85	2.9	3.0	4.7	275	9.3	15.1	23.7	715	24.2	14.9	23.4	1,075	36.3	33.0	51.9
131	13	−6	59.5	0.4	29.2	82.5	0.991	1.067	8.1	7.1	163	196	559	350	60	2.8	2.9	4.8	185	8.6	14.1	23.5	575	26.9	15.0	25.0	820	38.3	32.0	53.4
132	13	−2	57.5	0.5	29.0	82.0	0.983	1.041	8.0	6.5	130	170	161	529	65	3.0	2.5	4.3	210	9.6	14.0	24.1	565	25.6	14.1	24.3	840	38.5	30.6	52.8
133	13	+6	59.0	0.4	30.0	95.0	0.980	1.043	8.2	5.6	165	202	−314	180	75	3.0	2.6	4.4	225	8.9	14.0	23.6	635	25.2	13.9	23.4	935	37.1	30.5	51.4
134	13	+10	60.2	0.6	30.2	74.4	0.980	1.050	7.5	5.5	120	165	28	794	60	3.1	2.6	4.3	195	10.0	14.6	24.0	465	23.7	14.8	24.3	720	36.7	32.0	52.6
135	13	+12	58.0	0.6	30.0	73.0	1.003	1.053	6.0	5.2	94	133	−491	780	65	3.4	2.4	4.1	185	9.6	14.0	23.9	470	24.5	15.6	23.2	720	37.5	30.0	51.2
136	13	+20	55.8	0.2	28.8	69.0	0.973	1.039	6.3	4.5	94	165	450	549	60	3.3	2.9	5.2	165	9.0	12.6	22.5	415	22.6	13.0	23.2	640	34.8	28.5	50.9
137	13	+37	59.5	0.5	31.0	67.8	0.984	1.043	6.5	4.5	110	148	−335	1,179	65	3.6	2.6	4.3	165	9.2	13.9	23.2	485	26.9	13.5	22.5	715	39.7	30.0	50.0
138	13	+46	57.0	1.0	28.3	83.0	0.980	1.042	8.0	6.0	142	176	−11	62	80	3.6	3.0	5.2	260	11.8	13.5	23.3	585	26.5	14.0	24.1	925	42.0	30.5	52.6
139	13	+48	58.6	0.4	28.5	76.0	0.976	1.046	8.3	5.5	142	176	181	300	85	4.2	2.9	4.9	235	11.7	14.7	24.9	515	25.6	14.0	23.7	835	41.5	31.6	53.6
140	13	+52	57.3	0.7	28.0	80.0	0.985	1.046	8.2	6.0	130	162	149	75	75	3.5	2.8	4.8	225	10.6	14.5	25.0	545	25.7	13.7	23.6	845	39.9	31.0	53.5
141	13	+55	56.0	0.5	27.1	76.2	0.983	1.039	7.5	5.9	122	155	−51	−35	75	3.7	3.0	5.3	210	10.4	14.0	24.8	500	29.1	13.8	24.4	875	43.2	30.8	54.5
Mean	13	+15	58.1	0.5	29.3	81.0	0.992	1.049	7.7	5.7	139	175	8	390	70	3.3	2.8	4.7	211	9.9	14.0	23.8	582	25.6	13.8	23.6	821	38.8	30.5	52.1
15	13	−178	63.9	0.3	31.4	94.5	0.954	1.010	8.8	5.5	168	210	2	496	75	2.9	3.2	5.0	205	7.9	16.3	25.4	690	26.5	15.3	23.8	970	37.3	34.8	54.2
16	13	−173	64.2	0.2	33.4	100.0	1.021	1.081	9.5	6.0	152	201	508	1,166	70	2.7	2.6	4.0	230	9.0	15.2	23.6	670	26.2	15.9	24.7	970	37.9	33.7	52.3
17	13	−164	64.1	0.6	31.3	113.7	0.978	1.029	9.0	6.9	159	261	162	6	100	3.3	2.9	4.5	305	10.0	15.5	24.0	805	26.3	15.8	24.4	1,210	39.5	34.2	52.9
18	13	−23	59.5	0.7	30.5	78.0	0.984	1.049	8.0	5.0	135	177	−186	777	50	2.4	3.0	5.0	250	12.1	14.5	24.1	450	21.8	15.0	24.9	750	36.4	32.5	54.0
19	13	0	58.7	0.9	29.2	90.5	1.001	1.080	9.0	6.0	182	193	343	170	70	3.0	2.8	4.7	230	9.9	14.2	23.8	600	25.9	15.0	25.2	900	38.8	32.0	53.7
20	13	+20	61.0	0.2	31.0	89.0	0.977	1.044	8.8	6.0	163	188	264	619	50	2.1	2.5	4.1	180	7.6	15.2	24.8	650	27.5	15.0	24.5	885	37.3	32.7	53.4
21	13	+28	61.8	0.2	31.0	98.0	0.977	1.045	8.2	6.0	178	212	58	321	60	2.3	2.8	4.5	250	9.6	14.0	22.6	730	28.1	14.4	23.2	1,040	40.0	31.2	50.3
22	13	+30	62.4	0.6	32.4	112.0	0.973	1.031	9.0	6.5	178	231	−40	391	100	3.3	3.0	4.8	340	11.3	14.5	23.0	760	25.3	14.5	23.0	1,200	39.9	32.0	50.7
23	13	+69	59.4	0.6	30.4	86.0	0.987	1.054	8.0	5.2	153	178	−228	349	58	2.6	2.6	4.3	172	7.6	13.8	23.0	680	30.1	14.6	24.3	910	40.3	31.0	51.7
24	13	+71	58.8	1.2	30.2	95.0	0.952	1.004	9.0	6.3	143	204	47	134	85	3.2	2.9	4.8	215	8.2	13.9	23.2	590	22.5	13.7	22.8	890	34.0	30.5	50.8
25	13	+106	60.4	0.9	30.4	78.0	0.972	1.049	8.0	6.3	161	186	400	749	80	3.9	3.0	4.9	200	9.7	15.0	24.5	490	23.8	14.0	22.8	770	37.4	32.0	52.2
26	13	+168	62.8	0.2	30.9	91.0	0.996	1.065	9.5	6.3	163	177	713	585	64	2.7	3.0	4.8	191	8.1	15.3	24.3	600	25.4	15.2	24.1	855	36.2	33.5	53.2
27	13	+181	66.8	0.6	33.0	138.8	0.982	1.031	8.9	7.1	185	341	−372	−136	102	2.7	2.9	4.3	298	8.0	16.0	23.7	1,000	26.8	16.5	24.5	1,400	37.5	35.4	52.5
Mean	13	+10	61.8	0.55	31.1	97.3	0.981	1.044	8.7	6.1	163	212	129	448	74	2.9	2.9	4.6	236	9.2	14.9	23.8	670	25.9	15.0	24.0	980	37.9	32.7	52.5
Mean	13	+13	59.9	0.55	30.2	88.8	0.987	1.047	8.2	5.9	151	193	66	419	72	3.1	2.8	4.6	223	9.6	14.4	23.8	606	25.8	14.4	23.8	901	38.4	31.6	52.3
142	14	−37	61.3	0.7	30.2	94.0	0.985	1.040	7.3	6.3	143	170	−274	254	80	3.2	3.1	5.0	240	9.6	15.4	24.8	595	23.8	14.5	23.4	915	36.6	33.0	53.2
143	14	−31	59.5	0.5	30.4	92.5	0.990	1.055	9.0	6.5	163	200	418	384	75	3.1	2.9	4.8	255	10.5	14.5	24.2	660	27.2	14.6	24.3	990	40.8	32.0	53.3
144	14	−22	61.6	0.4	32.0	105.0	0.983	1.038	8.0	5.8	158	202	−497	477	65	2.3	2.6	4.2	280	10.0	14.0	22.6	595	21.3	14.4	23.2	940	33.6	31.0	50.0
145	14	−9	56.5	0.5	28.2	78.2	0.984	1.041	7.5	3.5	119	181	96	170	65	3.1	2.6	4.6	155	7.5	13.7	24.0	540	26.0	13.7	24.0	760	36.5	30.0	52.6
146	14	−2	61.3	0.7	33.0	110.0	0.974	1.043	9.0	6.2	208	305	−139	674	70	2.4	2.8	4.5	235	8.1	13.5	21.8	755	25.9	13.7	22.1	1,060	36.3	30.0	48.4
147	14	+3	59.5	0.5	31.0	69.0	0.985	1.061	7.8	6.2	140	190	490	1,179	55	3.1	2.6	4.3	185	10.3	13.9	23.2	425	23.6	13.5	22.5	665	36.9	30.0	50.0

TABLE 49.—*Data and Detailed Measurements of One Hundred and Sixty-Four Boys Measured by Water Displacement *—Continued*

			Item Number																										
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
148	14 +13	60.0	1.0	31.2	82.0	0.979	1.032	7.7	5.9	118	182	−21	837	65	3.0	3.0	4.9	175	8.0	13.8	22.6	600	27.3	14.0	23.0	840	38.2	30.8	50.5
149	14 +14	64.0	1.0	32.0	122.0	0.968	1.036	9.0	7.0	230	310	−43	17	85	2.6	3.1	4.8	275	8.4	15.2	23.4	925	28.4	15.7	24.2	1,285	39.4	34.0	52.3
150	14 +20	60.5	0.5	30.1	115.0	0.980	1.034	8.0	6.0	170	215	−811	−353	70	2.3	2.8	4.6	250	8.1	15.0	24.6	940	30.5	14.2	23.3	1,260	40.9	32.0	52.5
151	14 +29	57.0	0.5	29.8	74.2	0.978	1.053	7.9	6.0	150	177	240	696	80	4.1	3.0	5.2	170	8.7	13.4	23.3	605	25.9	13.4	23.3	755	38.7	29.8	51.8
Mean 14	+2	60.1	0.6	30.8	94.2	0.981	1.043	8.1	6.2	160	213	−54	434	71	2.9	2.9	4.7	222	8.9	14.2	23.4	652	26.0	14.2	23.3	947	37.8	31.3	51.5
28	14 −176	57.4	0.2	28.5	74.8	0.972	1.036	8.5	5.5	130	190	594	315	58	2.9	2.6	4.5	182	9.1	13.7	23.8	500	25.0	13.7	23.8	740	37.0	30.0	52.1
29	14 −160	62.5	0.9	31.5	86.0	0.972	1.038	9.3	6.3	155	195	681	830	74	3.2	3.0	4.7	236	10.3	14.7	23.2	540	23.5	15.0	23.7	850	37.0	32.7	51.6
30	14 −130	65.6	0.2	33.6	125.0	0.984	1.038	9.0	7.5	180	255	129	458	116	3.5	3.3	5.0	339	10.2	15.1	23.0	625	24.7	14.3	21.7	1,280	38.4	32.7	49.7
31	14 −130	61.7	0.5	31.2	96.9	0.986	1.050	8.8	6.6	175	215	318	482	90	3.5	2.8	4.5	210	8.2	14.7	23.6	700	27.4	15.3	24.6	1,000	39.1	32.8	52.7
32	14 −92	71.3	0.3	36.3	157.5	1.013	1.089	11.5	8.0	298	388	1,373	778	110	2.8	3.0	4.2	370	9.2	16.5	23.0	1,050	26.2	16.5	23.0	1,530	38.2	36.0	50.3
33	14 −85	65.7	0.1	34.0	125.5	1.001	1.059	9.8	7.4	190	235	536	650	90	2.7	3.0	4.6	365	11.1	15.1	23.0	895	27.3	15.4	23.4	1,350	41.2	33.5	50.9
34	14 −85	62.4	0.5	32.1	110.0	0.976	1.032	9.5	6.5	172	223	187	358	110	3.7	2.9	4.6	305	10.3	14.8	23.5	715	24.2	14.5	23.1	1,130	38.3	32.2	51.2
35	14 −73	62.5	0.6	30.8	93.0	1.021	1.086	9.3	5.8	150	195	465	552	50	2.1	2.6	4.1	230	9.7	15.8	25.0	710	30.0	15.4	24.4	990	41.8	33.8	53.6
36	14 −57	68.6	0.0	34.3	113.5	1.002	1.061	9.7	6.6	175	225	663	1,075	64	2.2	2.8	4.1	276	9.3	16.0	23.3	690	23.3	15.6	22.7	1,030	34.8	34.4	50.2
37	14 −33	67.3	0.4	33.3	118.7	1.012	1.078	9.5	7.0	197	234	504	643	90	3.0	2.7	4.0	350	11.5	16.7	24.7	840	27.5	16.4	24.2	1,280	42.0	35.8	52.9
38	14 −28	64.5	0.5	32.5	114.5	0.968	1.051	9.0	6.5	260	261	67	418	60	2.0	3.4	5.2	260	8.6	14.4	22.1	860	28.5	15.2	23.3	1,180	39.1	33.0	50.5
39	14 −20	62.9	1.4	31.3	93.4	0.994	1.060	8.5	6.3	160	201	265	626	75	3.1	2.7	4.2	215	8.8	14.8	23.0	610	25.0	15.5	24.1	900	36.9	33.0	51.3
40	14 −10	62.7	0.7	32.4	107.0	1.000	1.058	9.3	6.3	165	238	196	401	60	2.1	3.3	5.2	270	9.6	14.7	23.2	760	27.1	15.0	23.7	1,090	38.9	33.0	52.1
41	14 −10	60.7	0.3	32.0	90.0	0.977	1.058	8.8	6.2	195	200	327	922	60	2.6	2.5	4.1	210	8.9	14.0	23.0	590	25.1	15.2	24.9	860	36.5	31.7	52.0
42	14 +10	60.0	0.5	31.0	117.0	0.987	1.042	9.0	6.6	172	233	−242	−131	65	2.1	2.5	4.1	375	12.1	14.8	24.4	870	28.0	14.5	24.0	1,310	42.1	31.8	52.5
43	14 +33	67.7	0.3	33.5	128.5	0.983	1.046	11.0	7.0	220	334	8	360	85	2.5	3.1	4.6	300	8.8	16.7	24.6	900	26.5	15.5	22.8	1,285	37.8	35.3	51.9
44	14 +76	68.5	0.7	34.5	122.5	0.985	1.047	9.5	7.0	204	292	378	866	110	3.4	3.0	4.3	360	11.1	16.3	23.6	820	25.3	15.5	22.4	1,290	39.8	34.8	50.3
45	14 +92	61.9	0.0	31.5	105.1	0.990	1.047	9.5	8.5	160	238	1,158	346	52	1.9	3.0	4.9	303	10.9	14.0	22.6	695	25.0	14.8	23.9	1,050	37.8	31.8	51.4
46	14 +104	54.3	1.2	27.6	75.0	0.965	1.038	8.5	5.0	153	184	−28	102	60	3.0	2.9	5.2	190	9.5	12.4	22.3	550	27.5	13.4	24.1	800	40.0	28.7	51.7
47	14 +140	62.6	0.6	31.5	87.0	0.984	1.043	8.0	5.8	138	191	31	815	82	3.6	3.4	5.4	218	9.4	15.1	23.9	620	26.8	14.8	23.4	920	39.8	33.3	52.7
48	14 +143	65.5	0.9	33.0	126.2	0.968	1.038	10.0	7.0	244	306	133	229	100	3.0	3.3	5.0	350	10.4	14.7	22.1	965	28.7	16.1	24.3	1,415	42.1	34.1	51.4
49	14 +174	62.5	0.5	32.5	103.5	0.992	1.061	9.0	6.8	187	322	364	733	60	2.2	2.6	4.1	200	7.4	14.6	23.2	795	29.4	15.6	24.8	1,055	39.1	32.8	52.1
Mean 14	−15	63.6	0.5	32.2	107.6	0.988	1.53	9.3	6.6	186	243	369	538	78	2.7	2.9	4.6	278	9.8	15.0	23.5	749	25.6	15.1	23.6	1,108	39.0	33.1	51.6
Mean 14	−10	62.5	0.5	31.7	103.4	0.986	1.049	8.9	6.5	178	234	236	505	76	2.8	2.9	4.6	265	9.5	14.8	23.5	719	25.7	14.8	23.5	1,058	38.6	32.5	51.5
152	15 −43	55.8	0.2	28.0	77.0	0.984	1.046	8.5	6.3	126	155	360	155	58	2.8	3.0	5.4	162	7.9	13.1	23.4	580	28.4	13.0	23.2	800	39.2	29.1	52.0
153	15 −40	65.0	0.5	32.1	96.0	0.980	1.052	8.5	6.3	188	206	270	783	80	3.2	3.0	4.6	270	10.7	15.5	23.7	620	24.6	16.0	24.4	970	38.4	34.5	52.7
154	15 −35	59.5	0.8	31.0	98.0	0.983	1.060	9.5	6.5	200	211	431	419	95	3.7	3.2	5.3	300	11.7	13.6	22.6	715	27.9	13.8	22.9	1,110	43.4	30.6	50.8
155	15 −31	59.3	0.7	30.5	90.0	0.978	1.053	8.0	6.8	184	190	185	472	65	2.8	2.7	4.5	190	8.0	13.8	23.0	580	24.5	13.3	22.2	835	35.3	29.8	49.7
156	15 −25	57.5	0.4	30.0	86.0	0.986	1.044	8.0	6.0	136	165	−67	420	75	3.3	2.8	4.8	185	8.1	12.8	22.1	640	28.1	13.8	23.8	900	39.5	29.4	50.8
157	15 −14	60.0	0.6	31.5	89.5	0.970	1.042	7.6	6.4	170	178	−81	736	55	2.3	2.7	4.5	195	8.2	13.4	22.1	645	27.0	14.1	23.3	895	37.5	30.2	49.8
158	15 −8	60.5	0.3	31.0	90.0	0.978	1.039	7.9	6.7	150	196	132	579	73	3.0	3.0	4.9	187	7.8	13.6	22.4	685	28.5	13.7	22.5	945	39.4	30.3	49.8
159	15 0	60.5	0.5	29.4	105.0	0.967	1.038	8.5	7.3	206	215	165	−259	70	2.5	2.7	4.4	245	8.8	14.8	24.3	875	31.3	15.2	24.9	1,190	42.5	32.7	53.6
160	15 +2	63.5	0.9	33.0	119.0	0.969	1.042	10.0	6.0	240	231	32	434	72	2.3	3.1	4.8	318	10.1	14.4	22.4	890	28.2	14.8	23.0	1,280	40.5	32.3	50.2
161	15 +9	61.0	1.0	30.8	100.0	0.976	1.047	8.0	7.0	192	210	50	277	80	3.0	3.1	5.0	315	11.9	14.3	23.1	680	25.7	15.0	24.2	1,075	40.6	32.4	52.3
162	15 +11	62.0	0.6	32.9	113.6	0.982	1.046	8.3	7.0	195	225	−197	551	85	2.8	2.9	4.6	225	7.5	14.0	22.4	815	27.1	14.1	22.5	1,125	37.4	31.0	49.5
163	15 +22	61.3	0.7	32.0	107.0	0.970	1.030	8.5	6.5	178	220	−167	402	85	3.0	3.1	5.0	235	8.2	13.5	21.8	765	26.6	14.2	22.9	1,085	37.7	30.8	49.7
164	15 +22	63.0	0.8	33.0	121.0	0.978	1.051	9.0	7.2	236	230	−30	404	85	2.7	3.0	4.7	235	7.4	14.5	22.7	850	26.7	14.1	22.1	1,170	36.7	31.6	49.5
165	15 +24	63.3	0.8	33.4	119.5	0.973	1.028	8.9	6.3	178	219	−248	560	85	3.0	3.2	5.0	245	7.6	14.6	22.8	940	29.2	14.4	22.5	1,280	39.8	32.2	50.2
166	15 +25	62.5	0.5	33.5	118.0	0.970	1.035	8.8	7.6	213	225	145	605	75	2.4	3.1	4.9	230	7.3	14.1	22.4	810	25.7	13.7	21.8	1,115	35.3	30.9	49.1
167	15 +30	61.3	0.7	31.2	90.0	0.971	1.039	8.0	6.0	166	190	−41	637	63	2.6	2.8	4.5	207	8.6	14.3	23.1	615	25.6	14.7	23.7	885	36.9	31.8	51.3
168	15 +57	64.3	0.9	32.2	115.0	0.980	1.026	9.0	6.8	151	202	52	239	85	2.7	2.9	4.5	260	8.4	15.8	24.2	1,005	32.4	16.1	24.7	1,350	43.6	34.8	53.4
169	15 +61	60.5	0.3	30.6	91.0	0.966	1.037	8.2	6.2	180	184	33	435	90	3.7	2.9	4.8	240	9.9	14.0	23.0	585	24.1	14.3	23.5	915	37.7	31.2	51.3
Mean 15	+4	61.1	0.6	31.5	101.4	0.976	1.042	8.5	6.6	183	203	57	442	77	2.9	2.9	4.8	236	8.8	14.1	22.8	739	27.3	14.4	23.3	1,051	39.0	31.4	50.9
50	15 −157	66.4	0.1	33.8	121.8	1.007	1.067	9.5	6.9	190	230	347	701	70	2.2	2.6	3.9	305	9.6	15.7	23.6	835	26.4	16.4	24.7	1,210	38.3	34.7	52.2

Mean	**15**	**+4**	**61.1**	**0.6**	**31.5**	**101.4**	**0.976**	**1.042**	**8.5**	**6.6**	**183**	**203**	**57**	**442**	**77**	**2.9**	**2.9**	**4.8**	**236**	**8.8**	**14.1**	**22.8**	**739**	**27.3**	**14.4**	**23.3**	**1,051**	**39.0**	**31.4**	**50.9**

50	15	—157	66.4	0.1	33.8	121.8	1.007	1.067	9.5	6.9	190	230	347	701	70	2.2	2.6	3.9	305	9.6	15.7	23.6	835	26.4	16.4	24.7	1,210	38.3	34.7	52.2
51	15	—138	62.3	0.2	31.4	100.0	1.003	1.073	9.3	6.2	190	210	397	516	90	3.5	2.7	4.3	280	10.9	14.0	22.4	685	26.6	15.8	25.3	1,055	40.9	32.5	52.0
52	15	—135	67.1	0.5	33.8	123.4	0.999	1.058	9.7	7.4	190	240	668	631	90	2.8	3.4	5.0	270	8.4	15.6	23.1	950	29.4	17.0	25.1	1,310	40.6	36.0	53.3
53	15	—85	67.1	0.4	35.3	131.1	0.973	1.028	9.8	7.3	200	250	368	869	96	2.7	3.0	4.4	294	8.3	15.1	22.4	930	28.8	15.3	22.7	1,320	37.4	33.4	49.5
54	15	—30	64.8	0.4	32.7	111.1	0.998	1.072	9.5	6.5	210	296	387	627	80	2.8	2.9	4.4	260	9.1	15.7	24.1	720	25.1	15.0	23.0	1,060	36.9	33.6	51.5
55	15	—27	69.0	0.4	36.2	134.5	0.993	1.055	10.3	7.5	220	310	667	1,227	95	2.7	3.2	4.6	285	8.1	16.0	23.1	900	25.5	16.4	23.6	1,280	36.3	35.6	51.3
56	15	—26	62.0	0.5	31.1	96.5	0.997	1.060	8.3	6.0	160	200	4	488	75	3.0	2.8	4.5	235	9.3	14.9	23.8	690	27.4	15.3	24.5	1,000	39.7	33.0	52.8
57	15	0	70.9	0.6	36.2	141.0	0.979	1.046	10.3	8.1	255	315	983	1,026	100	2.7	3.0	4.2	390	10.5	15.5	21.7	790	21.2	15.5	21.7	1,280	34.3	34.0	47.6
58	15	0	65.3	0.7	32.3	117.9	0.983	1.046	9.0	7.0	200	255	162	250	70	2.2	2.8	4.2	290	9.2	15.0	22.7	795	25.2	15.8	23.9	1,155	36.7	33.6	50.9
59	15	0	68.4	0.4	34.0	107.0	0.986	1.043	9.5	6.5	165	225	598	1,090	70	2.5	3.2	4.7	270	9.5	16.0	23.3	810	28.5	16.4	23.8	1,150	40.5	35.6	51.7
60	15	+9	70.8	0.8	36.6	133.0	0.992	1.070	10.3	6.5	270	300	484	1,463	80	2.3	2.7	3.8	320	9.3	17.0	23.7	960	27.9	17.1	23.9	1,360	39.5	36.8	51.4
61	15	+62	68.0	0.7	34.3	151.0	1.000	1.066	10.3	7.1	260	325	122	115	85	2.2	2.9	4.2	365	9.3	16.6	24.2	1,210	30.9	17.0	24.8	1,660	42.4	36.5	53.1
62	15	+96	67.6	0.9	34.9	128.3	0.989	1.051	9.8	6.8	210	270	278	871	110	3.3	3.0	4.4	345	7.3	14.9	21.8	790	28.7	16.1	23.5	1,245	36.8	34.0	49.6
63	15	+112	70.2	0.3	35.2	139.0	0.984	1.043	10.8	7.3	220	250	776	671	125	3.4	2.9	4.1	405	9.8	17.6	25.0	1,070	29.0	17.0	24.1	1,600	43.4	37.5	53.2
64	15	+119	65.1	0.4	31.8	128.5	1.013	1.075	8.8	6.0	200	225	—510	—94	100	3.0	3.2	4.9	285	8.6	16.3	24.9	905	27.3	15.5	23.7	1,290	39.0	35.0	53.4
65	15	+133	68.1	0.2	35.2	146.5	1.012	1.073	10.0	8.0	225	310	542	571	80	2.1	2.6	3.8	320	8.5	16.0	23.4	1,100	29.1	16.1	23.6	1,500	39.7	34.7	50.8
66	15	+145	66.2	1.2	34.5	123.5	1.011	1.068	10.5	5.5	180	260	128	906	90	2.8	3.0	4.5	260	8.1	16.0	23.7	850	26.6	16.8	24.9	1,200	37.5	35.8	53.1
67	15	+180	65.6	0.4	32.3	96.8	0.989	1.047	9.8	5.5	150	230	416	810	70	2.7	3.3	5.0	250	9.8	16.0	24.2	640	25.0	15.7	23.8	960	37.5	35.0	53.0
68	15	+183	66.0	0.7	33.4	106.5	0.981	1.053	8.5	6.8	205	280	194	926	80	2.9	3.3	5.0	260	9.3	14.7	22.0	680	24.3	15.0	22.5	1,020	36.4	33.0	49.5
Mean	**15**	**+24**	**66.9**	**0.5**	**34.0**	**123.0**	**0.994**	**1.058**	**9.7**	**6.8**	**205**	**262**	**369**	**719**	**87**	**2.7**	**3.0**	**4.4**	**299**	**9.1**	**15.7**	**23.3**	**858**	**26.8**	**15.5**	**23.8**	**1,245**	**38.6**	**34.8**	**51.6**
Mean	**15**	**+14**	**64.1**	**0.6**	**32.7**	**112.5**	**0.985**	**1.050**	**9.1**	**6.7**	**194**	**233**	**217**	**584**	**82**	**2.8**	**2.9**	**4.6**	**270**	**8.9**	**14.9**	**23.1**	**800**	**27.1**	**15.0**	**23.5**	**1,151**	**38.8**	**33.1**	**51.2**
68	16	—183	66.0	0.7	33.4	106.5	0.981	1.053	8.5	6.8	205	280	194	926	80	2.9	3.3	5.0	260	9.3	14.7	22.0	680	24.3	15.0	22.5	1,020	36.4	33.0	49.5
69	16	—181	70.8	0.0	35.3	149.0	0.994	1.053	10.5	7.3	230	320	485	479	115	2.9	3.0	4.2	385	9.8	16.3	23.0	1,200	30.6	17.4	24.6	1,700	43.4	36.7	51.8
70	16	—131	67.2	0.8	34.5	135.5	1.003	1.060	9.5	6.5	200	292	—122	566	80	1.7	3.0	4.4	250	7.1	15.3	22.5	950	27.4	15.7	23.1	1,280	36.2	34.0	50.0
71	16	—95	62.6	0.2	31.6	102.5	0.982	1.047	9.5	6.5	180	220	437	445	92	3.4	2.4	3.8	268	9.9	15.0	23.9	790	29.2	15.8	25.2	1,150	42.4	33.2	52.9
72	16	—82	73.0	1.0	38.0	149.0	1.015	1.084	10.7	6.9	260	300	635	1,682	80	2.1	2.6	3.2	350	9.2	17.4	23.5	1,025	26.9	17.7	23.9	1,455	38.2	37.7	50.9
73	16	—71	68.7	1.0	35.8	151.5	0.986	1.061	10.9	8.1	300	320	614	643	123	3.1	3.0	4.3	332	8.4	16.0	23.0	1,045	26.4	15.7	22.5	1,500	37.9	34.7	49.8
74	16	—26	71.8	0.5	36.8	140.0	1.007	1.075	11.0	6.6	245	240	280	1,379	110	3.1	3.0	4.1	365	10.1	17.0	23.5	915	25.4	17.0	23.5	1,390	38.6	37.0	51.2
75	16	+5	65.3	0.7	35.4	114.0	0.989	1.067	9.5	6.3	230	275	241	1,476	70	2.4	3.0	4.5	280	9.5	15.4	23.4	610	20.6	14.0	26.2	960	32.4	32.4	49.1
76	16	+24	67.8	0.1	34.7	121.0	0.987	1.060	10.3	6.5	220	280	597	1,018	95	3.0	3.5	5.2	285	9.0	15.8	23.3	750	23.7	16.1	23.7	1,130	35.8	35.4	52.1
77	16	+74	70.2	0.4	36.4	133.7	1.021	1.092	10.0	7.0	235	250	504	1,433	92	2.7	3.1	4.4	293	8.6	16.4	23.2	935	27.6	16.5	23.4	1,320	38.9	36.0	51.0
78	16	+78	66.9	0.6	33.2	113.0	0.984	1.050	9.8	5.5	200	230	71	679	100	3.4	3.2	4.7	300	10.1	15.8	23.4	570	25.2	15.3	22.7	1,150	38.6	34.3	50.8
79	16	+80	66.3	0.3	33.6	109.8	0.984	1.049	9.5	6.5	190	245	601	893	80	2.8	3.3	5.0	270	9.3	15.2	22.8	700	24.1	15.2	22.8	1,050	36.2	33.7	50.6
80	16	+101	65.2	0.3	33.7	104.7	0.992	1.051	9.0	7.2	160	220	517	1,067	105	3.8	2.8	4.3	250	9.1	15.0	22.9	670	24.3	15.6	23.8	1,025	37.1	33.4	51.0
81	16	+122	68.0	0.4	36.1	136.7	1.014	1.087	9.8	7.0	250	270	288	1,225	100	2.9	2.8	4.1	380	10.9	15.7	23.0	900	25.9	15.1	22.1	1,380	39.7	33.6	49.1
82	16	+123	66.0	1.2	34.6	126.0	0.969	1.045	10.5	7.5	260	285	859	802	90	2.7	3.0	4.5	300	9.0	15.0	22.3	910	27.2	15.9	23.7	1,300	38.9	33.9	50.4
83	16	+143	70.7	1.3	35.0	173.0	0.989	1.039	11.5	7.8	230	360	507	—323	110	2.4	3.2	4.4	420	9.1	16.5	22.9	1,320	28.6	17.3	24.0	1,850	40.3	37.0	51.4
84	16	+161	68.6	0.0	35.7	139.0	0.977	1.043	11.2	7.3	250	300	870	859	98	2.7	3.1	4.5	342	9.3	15.4	22.4	915	24.8	14.8	21.6	1,355	36.7	33.3	48.5
Mean	**16**	**+8**	**67.9**	**0.55**	**34.9**	**129.7**	**0.992**	**1.060**	**10.1**	**6.9**	**226**	**276**	**469**	**896**	**95**	**2.8**	**3.0**	**4.4**	**314**	**9.3**	**15.8**	**23.0**	**886**	**26.0**	**15.9**	**23.2**	**1,295**	**38.1**	**34.7**	**50.6**
85	17	—146	69.2	0.8	33.4	122.0	0.996	1.086	9.9	6.3	280	310	456	616	85	2.7	3.0	4.3	300	9.6	17.4	24.9	975	31.4	18.3	26.1	1,360	43.7	38.7	55.3
86	17	—133	71.1	1.0	35.3	115.5	0.977	1.050	9.6	7.5	230	340	1,037	1,354	115	3.8	3.3	4.6	240	7.9	17.2	23.9	775	25.5	17.3	24.0	1,130	37.0	37.8	52.4
87	17	—92	66.9	0.1	34.1	134.7	0.984	1.068	11.0	8.0	300	325	1,252	475	110	3.2	2.7	4.0	340	9.7	15.6	23.3	915	26.2	15.5	23.1	1,365	39.1	33.8	50.4
88	17	—64	68.2	0.6	34.2	129.0	1.006	1.038	10.2	6.8	210	320	530	660	74	2.2	3.0	4.4	366	11.0	16.3	23.7	925	27.7	17.1	24.9	1,365	40.9	36.4	52.9
89	17	—30	68.9	0.8	35.0	152.1	0.991	1.056	10.9	7.6	260	345	640	298	94	2.4	3.0	4.3	341	8.5	15.9	22.8	1,120	28.1	16.4	23.5	1,555	38.8	35.3	50.6
90	17	+11	68.5	0.9	35.4	157.5	0.982	1.074	11.0	7.8	280	360	693	389	110	2.7	3.0	4.3	390	9.6	16.5	23.8	1,120	27.6	17.0	24.5	1,620	39.9	36.5	52.6
91	17	+15	72.8	1.2	37.4	151.0	0.995	1.061	10.8	6.8	260	350	488	1,291	100	2.5	3.0	4.0	355	9.0	17.4	23.5	975	24.7	17.6	23.8	1,430	36.3	38.0	51.4
92	17	+28	72.1	1.5	38.1	146.0	1.003	1.064	10.5	7.8	230	300	992	1,730	95	2.5	3.7	5.0	330	8.7	16.5	22.4	975	25.7	17.3	23.5	1,400	36.8	37.5	51.0
Mean	**17**	**—51**	**69.7**	**0.86**	**35.4**	**138.5**	**0.992**	**1.062**	**10.5**	**7.3**	**256**	**331**	**761**	**852**	**98**	**2.8**	**3.1**	**4.4**	**333**	**9.3**	**16.6**	**23.5**	**973**	**27.1**	**17.1**	**24.2**	**1,406**	**38.5**	**36.8**	**52.1**
93	18	—90	71.8	1.5	37.6	156.5	1.003	1.083	10.5	7.0	208	300	309	1,316	85	2.1	3.0	4.1	315	7.9	16.5	22.5	1,080	27.0	16.3	22.2	1,480	37.0	35.8	48.8
94	19	—7	64.6	0.4	33.1	128.0	0.996	1.074	9.8	6.3	158	330	—12	637	70	2.1	3.2	4.9	280	8.5	13.8	21.2	790	23.9	14.2	21.8	1,140	34.5	31.2	48.0

TABLE 49.—*Data and Detailed Measurements of One Hundred and Sixty-Four Boys Measured by Water Displacement *—Continued*

* Key to Table.—In this table, boys of the university group have numbers less than 100. Boys of the settlement group have numbers 100 or over. The following key is explanatory of the "Item Numbers" appearing at the top of the columns.

1. Case number instead of name of subject (see foregoing statements).
2. Age: year plus or minus number of days.
31. Volume of loin to nearest cubic inch.
32. Volume of loin in percentage of total volume.
33. Height of loin to nearest tenth of an inch.
34. Height of loin in percentage of total height.
35. Volume of abdomen to nearest cubic inch.
36. Volume of abdomen in percentage of total volume.
37. Height of abdomen to nearest tenth of an inch.
38. Height of abdomen in percentage of total height.
39. Volume of chest to nearest cubic inch.
40. Volume of chest in percentage of total volume.
41. Height of chest to nearest tenth of an inch.
42. Height of chest in percentage of total height.
43. Volume of total trunk to nearest cubic inch.
44. Volume of total trunk in percentage of total volume.
45. Height of total trunk to nearest tenth of an inch.
46. Height of total trunk in percentage of total height.
47. Volume of neck to nearest cubic inch.
48. Volume of neck in percentage of total volume.
49. Height of neck to nearest tenth of an inch.
50. Height of neck in percentage of total height.
51. Volume of the cranium to nearest cubic inch.
52. Volume of the cranium in percentage of total volume.
53. Height of cranium to nearest tenth of an inch.
54. Height of cranium in percentage of total height.
55. Volume of total head to nearest cubic inch.
56. Volume of total head in percentage of total volume.
57. Height of total head to nearest tenth of an inch.
58. Height of total head in percentage of total height.
59. Total volume to nearest cubic inch.

			Item Number																											
1	2		31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59
1	5	0	200	15.8	4.8	10.9	240	19.0	5.3	12.0	185	14.6	4.8	10.9	625	49.4	14.9	33.7	60	4.7	4.3	9.7	150	11.8	5.0	11.3	210	16.6	9.3	21.0	1,265
101	6	−10	220	18.3	5.5	11.5	130	10.8	6.5	13.6	110	9.2	5.0	10.5	460	38.3	17.0	35.6	70	5.8	4.3	9.0	150	12.4	4.5	9.4	220	18.3	8.8	18.4	1,200
102	6	+14	200	16.1	6.5	13.3	160	12.9	5.5	11.2	160	12.9	5.5	11.2	520	41.9	17.5	35.7	90	7.3	4.1	8.4	150	12.1	4.4	9.0	240	19.4	8.5	17.4	1,240
Mean	6	+2	210	17.2	6.0	12.4	145	11.9	6.0	12.4	135	11.0	5.3	10.4	490	40.1	17.3	35.6	80	6.5	4.2	8.7	150	12.3	4.5	9.2	230	18.8	8.7	17.9	1,220
103	7	+2	200	13.0	3.8	7.6	240	15.6	6.3	12.6	230	14.9	6.5	13.0	670	43.5	16.6	33.2	90	5.8	4.6	9.2	160	10.4	4.6	9.2	250	16.2	9.2	18.4	1,540
104	8	+7	270	16.7	4.5	9.2	290	18.6	5.5	11.2	200	12.8	5.5	11.2	760	48.7	15.5	31.6	70	4.5	4.5	9.2	140	9.0	4.5	9.2	210	13.5	9.0	18.4	1,560
105	9	−42	190	11.2	4.3	8.2	255	15.1	5.8	11.1	295	17.5	6.1	11.7	740	43.8	16.2	31.0	100	5.9	4.3	8.2	160	9.5	4.9	9.4	260	15.4	9.2	17.6	1,690
106	9	−15	260	15.3	3.5	6.8	280	16.5	6.0	11.6	285	16.8	6.5	12.7	825	48.5	16.0	31.1	85	5.0	4.9	9.5	165	9.7	5.5	10.7	250	14.7	10.4	20.2	1,700
107	9	+30	220	13.3	4.7	9.0	280	16.9	6.0	11.4	300	18.1	5.3	10.1	800	48.2	16.0	30.5	100	6.0	4.6	8.8	160	9.6	4.6	8.8	260	15.7	9.2	17.5	1,660
Mean	9	−9	223	13.3	4.2	8.0	272	16.1	5.9	11.4	293	17.4	6.0	11.5	788	46.8	16.1	30.9	95	5.7	4.6	8.8	162	9.6	5.0	9.6	257	15.3	9.6	18.5	1,683
108	10	−27	240	13.3	4.0	7.5	360	20.0	7.0	13.1	260	14.4	6.4	12.0	860	47.8	17.4	32.6	120	6.7	4.5	8.4	160	8.9	5.0	9.4	280	15.6	9.5	17.8	1,800
109	10	−25	280	17.4	5.5	10.2	300	18.6	6.5	12.1	185	11.5	6.0	11.2	765	47.5	18.0	33.5	75	4.7	4.8	8.9	155	9.6	5.0	9.3	230	14.3	9.8	18.2	1,610
110	10	−17	255	14.5	5.0	8.2	350	19.9	8.0	14.0	270	15.3	6.7	11.8	875	49.7	19.7	34.6	135	7.7	4.8	8.4	145	8.2	5.2	9.1	280	15.9	10.0	17.5	1,760
111	10	−12	280	16.7	4.5	8.0	300	17.9	7.0	12.5	305	18.2	5.5	9.8	1,000	49.0	18.5	33.6	108	5.3	5.2	9.5	172	8.4	5.3	9.6	280	13.7	10.5	19.1	2,040
112	10	+20	300	17.7	6.0	10.9	315	15.4	6.5	11.8	325	15.9	6.0	10.9	885	52.7	17.0	30.4	85	5.1	6.0	10.7	160	9.5	5.5	9.8	245	14.6	11.5	20.5	1,680
Mean	10	−12	283	15.9	5.0	9.0	325	18.4	7.0	12.7	269	15.1	6.1	11.1	877	49.3	18.1	32.9	105	5.9	5.1	9.2	158	8.9	5.2	9.5	263	14.8	10.3	18.6	1,778
2	10	+24	590	23.1	6.5	11.0	400	15.6	6.2	10.6	410	16.0	6.5	11.0	1,400	54.7	19.2	32.6	150	5.9	5.8	9.8	160	6.3	5.5	9.3	310	12.1	11.3	19.1	2,560
Mean	10	−6	334	17.1	5.3	9.3	334	17.9	6.9	12.4	293	15.2	6.2	11.1	964	50.2	18.3	32.9	112	5.9	5.2	9.3	159	8.5	5.3	9.4	271	14.4	10.4	18.7	1,908
113	11	−30	220	15.2	5.0	9.1	240	16.6	6.0	10.9	220	15.2	6.5	11.8	680	46.9	17.5	31.8	70	4.8	5.2	9.5	140	9.7	5.3	9.6	210	14.5	10.5	19.1	1,450
114	11	−15	305	14.2	6.5	11.0	360	16.7	5.8	9.8	380	17.7	6.5	11.0	1,045	48.6	18.8	31.9	145	6.7	4.9	8.3	170	7.9	5.3	9.0	315	14.7	10.2	17.2	3,150
115	11	−10	315	19.2	5.4	10.0	245	14.9	4.5	8.3	200	12.2	5.5	10.2	760	46.3	15.4	28.5	95	5.8	5.4	10.0	165	10.1	5.4	10.0	260	15.9	10.8	20.0	1,640
116	11	0	255	12.8	4.2	8.1	390	19.5	5.3	10.2	310	15.5	5.5	10.6	955	47.8	15.0	28.9	135	6.8	4.6	8.9	155	7.8	5.2	10.0	290	14.5	9.8	18.9	2,000
117	11	0	225	13.8	5.4	9.7	280	17.2	5.0	9.0	200	12.3	5.6	10.1	705	43.3	16.0	28.8	105	6.4	5.0	9.0	155	9.5	5.5	9.9	260	16.0	10.5	18.9	1,630
118	11	+6	340	17.7	6.5	11.1	380	19.8	7.3	12.5	305	15.9	6.7	11.5	1,025	53.4	20.5	35.1	80	4.2	5.0	8.6	160	8.3	5.4	9.3	240	12.5	10.4	17.8	1,920
119	11	+19	370	19.1	7.2	11.4	340	17.5	7.8	12.4	345	17.8	7.0	11.1	1,055	54.4	22.0	34.9	95	4.9	5.2	8.3	145	7.5	5.2	8.3	240	12.4	10.4	16.5	1,940
120	11	+27	235	11.8	4.0	7.3	400	20.1	6.4	11.7	330	16.6	6.2	11.4	965	48.5	16.6	30.4	138	6.9	5.6	10.3	182	9.2	5.4	9.9	320	16.1	11.0	20.2	1,990
Mean	11	0	283	15.5	5.5	9.7	329	17.8	6.0	10.6	286	15.4	6.2	11.0	896	48.6	17.7	31.3	108	5.8	5.1	9.1	159	8.7	5.3	9.2	267	14.6	10.5	18.6	1,840
3	11	−30	280	15.9	5.3	9.3	290	16.4	6.1	10.7	300	17.0	5.6	9.8	870	49.3	17.0	29.7	75	4.3	5.0	8.7	140	7.9	5.2	9.1	215	12.2	10.2	17.8	1,765
4	11	+114	300	14.4	5.4	9.6	370	17.8	5.7	10.2	360	17.3	5.4	9.6	1,030	49.5	16.5	29.5	140	6.7	5.4	9.6	140	6.7	5.1	9.1	280	13.5	10.5	18.8	2,080
Mean	11	+42	290	15.1	5.4	9.5	330	17.1	5.9	10.4	330	17.2	5.5	9.7	950	49.4	16.8	29.6	108	5.5	5.2	9.2	140	7.3	5.2	9.1	248	13.3	10.4	18.3	1,922
Mean	11	+8	285	15.4	5.5	9.7	330	17.7	6.0	10.6	295	15.7	6.0	10.7	909	48.8	17.5	31.0	108	5.8	5.1	9.1	155	8.5	5.3	9.2	263	14.3	10.5	18.5	1,857
121	12	−44	205	12.5	4.0	7.7	295	18.0	6.0	11.5	295	18.0	6.5	12.5	795	48.5	16.5	31.7	135	8.2	4.8	9.2	145	8.8	5.2	10.0	280	17.1	10.0	19.2	1,640
122	12	−9	265	12.0	5.3	8.8	330	15.0	7.0	11.7	395	17.9	6.4	10.7	990	44.9	18.7	31.2	120	5.4	5.1	8.5	165	7.5	5.5	9.2	285	12.9	10.6	17.7	2,205
123	12	0	280	15.1	4.5	8.3	385	19.4	6.4	11.9	345	17.4	5.6	10.4	1,010	51.0	16.5	30.6	80	4.0	4.7	8.7	175	8.8	5.3	9.8	255	12.9	10.0	18.5	1,980

121	12	−44	205	12.5	4.0	7.7	295	18.0	6.0	11.5	295	18.0	6.5	12.5	795	48.5	16.5	31.7	135	8.2	4.8	9.2	145	8.8	5.2	10.0	280	17.1	10.6	19.2	1,840
122	12	−9	265	12.0	5.3	8.8	330	15.0	7.0	11.7	395	17.9	6.4	10.7	990	44.9	18.7	31.2	120	5.4	5.1	8.5	165	7.5	5.5	9.2	285	12.9	10.6	17.7	2,205
123	12	0	280	15.1	4.5	8.3	385	19.4	6.4	11.9	345	17.4	5.6	10.4	1,010	51.0	16.5	30.6	80	4.0	4.7	8.7	175	8.8	5.3	9.8	255	12.9	10.0	18.5	1,980
124	12	+17	350	14.0	4.5	7.7	385	15.4	6.7	11.5	545	21.8	7.3	12.5	1,280	51.2	18.5	31.7	120	4.8	5.7	9.8	170	6.8	5.2	8.9	290	11.6	10.9	18.7	2,500
125	12	+20	315	15.4	4.5	7.9	365	17.9	6.8	11.9	320	15.7	6.0	10.5	990	48.5	17.3	30.4	117	5.7	5.5	9.7	168	8.2	5.2	9.1	285	14.0	10.7	18.8	2,040
126	12	+24	415	17.2	6.0	10.2	390	16.2	5.2	8.8	445	18.5	5.8	9.8	1,250	51.9	17.0	28.8	110	4.6	6.2	10.5	175	7.3	5.3	9.0	285	11.8	11.5	19.5	2,410
127	12	+61	300	11.4	4.0	6.7	575	21.8	8.3	13.9	515	19.5	6.2	10.4	1,390	52.7	18.5	31.0	118	4.5	5.3	8.9	172	6.5	5.3	8.9	290	11.0	10.6	17.8	2,640
Mean	**12**	**+10**	**304**	**13.8**	**4.7**	**8.2**	**389**	**17.7**	**6.6**	**11.6**	**409**	**18.4**	**6.2**	**11.0**	**1,101**	**49.9**	**17.6**	**30.8**	**114**	**5.3**	**5.3**	**9.5**	**167**	**7.7**	**5.3**	**9.3**	**281**	**13.0**	**10.6**	**18.6**	**2,202**
5	12	−120	310	15.5	5.1	8.9	325	16.2	6.2	10.8	365	18.2	6.4	11.1	1,000	49.9	17.7	30.9	140	7.0	4.9	8.6	145	7.2	5.4	9.4	285	14.2	10.3	18.0	2,005
6	12	−89	295	13.7	5.0	8.8	395	18.3	7.0	12.3	350	16.2	5.3	9.3	1,040	48.2	17.3	30.5	160	7.4	5.7	10.0	130	6.0	5.3	9.3	290	13.4	11.0	19.4	2,160
7	12	+20	350	14.2	5.5	9.0	450	18.2	7.5	12.2	390	15.8	5.5	9.0	1,190	48.2	18.5	30.1	140	5.7	5.7	9.3	170	6.9	5.2	8.5	310	12.6	10.9	17.8	2,470
8	12	+21	210	11.5	5.3	9.0	320	17.6	6.1	10.4	350	19.2	7.0	11.9	880	48.4	18.4	31.3	90	5.0	5.5	9.4	150	8.2	4.6	7.8	240	13.2	10.1	17.2	1,820
9	12	+22	425	16.5	6.6	10.9	370	14.3	5.5	9.1	435	16.9	7.7	12.7	1,230	47.7	19.8	32.6	160	6.2	5.5	9.1	175	6.8	5.0	8.2	335	13.0	10.5	17.3	2,580
10	12	+22	300	14.9	5.0	9.0	300	14.9	5.2	9.4	400	19.8	6.2	11.2	1,000	49.5	16.4	29.5	120	5.9	5.8	10.4	160	7.9	5.4	9.7	280	13.9	11.2	20.1	2,020
11	12	+68	420	17.0	5.8	9.5	430	17.4	7.0	11.5	400	16.8	6.2	10.2	1,250	50.6	19.0	31.2	140	5.7	5.6	9.2	150	6.1	5.4	8.9	290	11.7	11.0	18.0	2,470
12	12	+121	390	16.4	5.8	9.5	400	16.8	6.1	10.0	400	16.8	5.9	9.6	1,190	50.0	17.8	29.1	110	4.6	6.2	10.1	150	6.3	5.5	9.0	260	10.9	11.7	19.1	2,380
13	12	+178	485	15.9	5.7	9.2	505	16.6	6.4	10.4	570	18.7	7.3	11.8	1,560	57.2	19.4	31.4	170	5.6	5.7	9.2	170	5.6	5.3	8.6	340	11.2	11.0	17.8	3,050
14	12	+180	385	13.3	5.0	7.8	460	15.9	7.5	11.7	480	16.6	5.8	9.0	1,325	45.9	18.3	28.4	175	6.1	6.2	9.6	175	6.1	5.2	8.1	350	12.1	11.4	17.7	2,890
Mean	**12**	**+42**	**357**	**14.9**	**5.5**	**9.2**	**396**	**16.6**	**6.5**	**10.8**	**414**	**17.4**	**6.3**	**10.6**	**1,167**	**48.8**	**18.3**	**30.5**	**141**	**5.9**	**5.7**	**9.5**	**158**	**6.7**	**5.2**	**8.7**	**298**	**12.6**	**10.9**	**18.2**	**2,385**
Mean	**12**	**+29**	**335**	**14.4**	**5.2**	**8.8**	**393**	**17.0**	**6.5**	**11.1**	**412**	**17.8**	**6.3**	**10.7**	**1,139**	**49.2**	**18.0**	**30.6**	**130**	**5.7**	**5.5**	**9.5**	**162**	**7.1**	**5.3**	**9.0**	**291**	**12.8**	**10.8**	**18.4**	**2,309**
128	13	−34	295	13.4	5.5	9.4	360	16.4	5.5	9.4	350	15.9	5.8	9.9	1,005	45.7	16.8	28.6	132	6.0	6.6	11.2	178	8.1	5.5	9.4	310	14.1	12.1	20.6	2,200
129	13	−21	245	12.0	4.4	8.2	340	16.7	6.8	12.6	400	19.6	5.8	10.7	995	48.8	17.0	31.5	110	5.4	5.2	9.6	170	8.3	4.8	8.9	280	13.7	10.0	18.5	2,040
130	13	−11	340	11.5	4.5	7.1	675	22.8	7.0	11.0	530	17.9	6.5	10.2	1,545	52.2	18.0	28.3	160	5.4	7.1	11.2	180	6.1	5.5	8.7	340	11.5	12.6	19.8	2,960
131	13	−6	280	13.1	4.5	7.5	295	13.8	6.0	10.0	430	20.1	7.0	11.7	1,005	47.0	17.5	29.2	140	6.5	5.4	9.0	175	8.2	5.0	8.4	315	14.7	10.4	17.4	2,140
132	13	−2	375	17.2	5.0	8.6	300	13.8	5.0	8.6	375	17.2	5.8	10.0	1,050	48.2	15.8	27.2	120	5.5	6.3	10.9	170	7.8	5.3	9.1	290	13.3	11.6	20.0	2,180
133	13	+6	375	14.9	5.0	8.4	360	14.3	6.0	10.1	500	19.8	6.9	11.6	1,235	49.0	17.9	30.1	170	6.8	5.5	9.3	180	7.1	5.5	9.3	350	13.9	11.0	18.5	2,520
134	13	+10	275	14.0	4.2	6.9	300	15.3	6.3	10.4	415	21.2	6.7	11.0	990	50.5	17.2	28.3	95	4.9	6.8	11.2	155	7.9	4.8	7.9	250	12.8	11.6	19.1	1,960
135	13	+12	245	12.8	5.0	8.5	330	17.2	6.4	10.9	325	16.9	6.1	10.4	900	46.9	17.5	29.9	115	6.0	5.5	9.4	185	9.6	5.6	9.6	300	15.6	11.1	18.9	1,920
136	13	+20	200	10.9	3.5	6.3	360	19.6	7.0	12.5	340	18.5	5.8	10.4	900	48.9	16.3	29.1	122	6.6	5.6	10.0	178	9.7	5.6	10.0	300	16.3	11.2	20.0	1,840
137	13	+37	235	13.1	4.5	7.5	335	18.6	6.5	10.8	275	15.3	7.2	12.0	845	46.9	18.2	30.3	85	4.7	6.4	10.7	155	8.6	5.4	9.0	240	13.3	11.8	19.7	1,800
138	13	+46	265	12.0	4.5	7.8	450	20.4	5.7	9.8	305	13.8	5.5	9.5	1,020	46.3	15.7	27.1	120	5.4	6.6	11.4	140	6.4	5.2	9.0	260	11.8	11.8	20.3	2,205
139	13	+48	305	15.2	5.0	8.5	315	15.7	6.0	10.2	315	15.7	5.8	9.8	935	46.6	16.8	28.5	95	4.7	5.6	9.5	145	7.2	5.0	8.5	240	11.9	10.6	18.0	2,010
140	13	+52	350	16.5	4.5	7.8	315	14.9	5.5	9.5	410	19.3	6.6	10.3	1,075	50.7	16.0	27.6	65	3.1	6.0	10.3	135	6.4	5.0	8.6	200	9.4	11.0	19.0	2,120
141	13	+55	300	14.8	4.0	7.1	290	14.3	5.0	8.9	295	14.6	5.9	10.4	885	43.7	14.9	26.4	100	4.9	5.7	10.1	165	8.2	5.1	9.0	265	13.1	10.8	19.1	2,025
Mean	**13**	**+15**	**292**	**13.7**	**4.6**	**7.8**	**359**	**16.7**	**6.1**	**10.3**	**376**	**17.6**	**6.2**	**10.6**	**1,028**	**48.0**	**16.8**	**28.8**	**116**	**5.4**	**6.0**	**10.3**	**165**	**7.8**	**5.2**	**9.0**	**282**	**13.2**	**11.3**	**19.2**	**2,137**
15	13	−178	410	15.8	5.2	8.1	620	23.9	7.0	10.9	320	12.3	6.8	10.6	1,350	51.9	19.0	29.6	110	4.2	5.3	8.3	170	6.5	5.1	7.9	280	10.8	10.4	16.2	2,600
16	13	−173	435	17.0	5.7	8.9	475	8.6	7.6	11.8	360	14.1	5.6	8.7	1,270	49.6	18.9	29.4	140	5.5	6.3	9.8	180	7.0	5.5	8.5	320	12.5	11.8	18.3	2,560
17	13	−164	490	16.0	5.3	8.2	485	15.9	7.1	11.0	515	16.8	6.4	9.9	1,490	48.7	18.8	29.1	190	6.2	6.4	9.9	170	5.6	5.3	8.2	360	11.8	11.7	18.1	3,060
18	13	−23	330	16.0	4.5	7.5	335	16.3	6.5	10.8	325	15.8	5.5	9.1	990	48.1	16.5	27.4	160	7.8	6.3	10.5	160	7.8	4.9	8.1	320	15.5	11.2	18.6	2,060
19	13	0	350	15.1	5.0	8.4	430	18.5	6.5	10.9	400	17.2	6.0	10.1	1,180	50.9	17.5	29.4	90	3.9	4.8	8.1	150	6.5	5.3	8.9	240	10.3	10.1	17.0	2,320
20	13	+20	320	13.6	4.0	6.5	400	17.0	6.0	9.8	450	19.1	6.8	11.0	1,170	49.6	16.8	27.4	130	5.5	6.3	10.2	180	7.6	5.5	9.0	310	13.1	11.8	19.2	2,360
21	13	+28	440	16.9	5.8	9.4	380	14.6	5.0	8.1	470	18.1	7.3	11.8	1,290	49.6	18.1	29.2	100	3.9	7.4	11.9	170	6.5	5.3	8.6	270	10.4	12.7	20.5	2,600
22	13	+30	465	15.5	6.2	9.8	510	16.9	7.4	11.8	540	17.9	6.5	10.3	1,515	50.3	20.1	31.9	125	4.2	5.7	9.1	170	5.7	5.2	8.3	295	9.8	10.9	17.3	3,010
23	13	+69	305	13.5	4.5	7.5	400	17.7	7.5	12.5	355	15.7	6.3	10.5	1,060	46.9	18.3	30.5	130	5.8	5.7	9.5	160	7.1	5.0	8.3	290	12.8	10.7	17.8	2,260
24	13	+71	470	17.9	5.2	8.7	490	18.7	7.3	12.2	480	18.3	6.5	10.8	1,440	55.0	19.0	31.7	140	5.3	5.5	9.2	150	5.7	5.0	8.3	290	11.1	10.5	17.5	2,620
25	13	+106	310	15.1	5.5	9.0	335	16.3	6.9	11.3	325	15.8	5.5	9.0	970	47.1	17.9	29.2	150	7.3	6.4	10.4	170	8.3	5.0	8.2	320	15.5	11.4	18.6	2,060
26	13	+168	385	16.3	5.7	9.1	445	18.8	7.3	11.6	405	17.1	5.5	8.7	1,235	52.2	18.5	29.4	115	4.8	6.0	9.5	160	6.8	5.0	7.9	275	11.6	11.0	17.5	2,365
27	13	+181	560	15.0	5.6	8.3	600	16.1	7.0	10.4	780	20.9	8.1	12.0	1,940	52.0	20.7	30.7	195	5.2	6.0	8.9	195	5.2	5.3	7.9	390	10.5	11.3	16.8	3,730
Mean	**13**	**+10**	**482**	**15.7**	**5.2**	**8.4**	**454**	**17.6**	**6.9**	**11.0**	**440**	**16.3**	**6.3**	**10.2**	**1,300**	**50.1**	**18.4**	**29.6**	**137**	**5.4**	**6.0**	**9.6**	**168**	**6.6**	**5.2**	**8.3**	**305**	**12.0**	**11.2**	**18.0**	**2,585**
Mean	**13**	**+13**	**346**	**14.6**	**4.9**	**8.1**	**405**	**17.1**	**6.4**	**10.7**	**407**	**17.2**	**6.3**	**10.4**	**1,160**	**49.0**	**17.6**	**29.1**	**126**	**5.4**	**6.0**	**10.0**	**167**	**7.3**	**5.2**	**8.6**	**293**	**12.6**	**11.2**	**18.6**	**2,353**
142	14	−37	330	13.2	5.0	8.1	510	20.4	6.0	9.7	425	17.0	6.8	11.0	1,265	50.6	17.8	28.7	150	6.0	6.0	9.7	170	6.8	5.2	8.4	320	12.8	11.2	18.1	2,500
143	14	−31	335	13.8	4.5	7.5	410	16.9	6.5	10.8	375	15.5	6.2	10.3	1,120	46.2	17.2	28.7	140	5.8	5.8	9.7	175	7.2	5.0	8.3	315	13.0	10.8	18.0	2,425
144	14	−22	490	17.5	5.7	9.2	500	17.9	6.0	9.7	430	15.4	7.3	11.8	1,520	54.3	19.0	30.7	155	5.5	6.4	10.3	185	6.6	5.6	9.0	340	12.1	12.0	19.4	2,800
145	14	−9	315	15.1	5.0	8.8	370	17.8	6.5	11.4	355	17.1	5.5	9.7	1,040	50.0	17.0	29.8	115	5.5	5.0	8.8	165	7.9	5.0	8.8	280	13.5	10.0	17.5	2,080
146	14	−2	400	13.7	5.0	8.1	520	17.8	7.8	12.6	610	20.8	7.2	11.6	1,530	52.4	20.0	32.3	160	5.5	6.6	10.7	170	5.8	5.4	8.7	330	11.3	12.0	19.4	2,920
147	14	+3	280	15.6	6.5	10.8	305	16.9	6.8	11.3	300	16.7	7.7	12.8	885	49.2	19.5	32.5	90	5.0	5.4	9.0	160	8.9	5.1	8.5	250	13.9	10.5	17.5	1,800

TABLE 49.—*Data and Detailed Measurements of One Hundred and Sixty-Four Boys Measured by Water Displacement*—Continued*

													Item Number																	
1	2	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59
148	14 +13	340	15.5	5.0	8.2	315	14.3	6.8	11.2	415	18.9	7.6	12.5	1,070	48.6	19.4	31.8	120	5.5	5.6	9.2	170	7.7	5.2	8.5	290	13.2	10.8	17.7	2,200
149	14 +14	395	12.1	5.5	8.5	590	18.1	7.0	10.8	640	19.6	6.4	9.9	1,625	49.9	18.9	29.1	170	5.2	6.7	10.3	180	5.5	5.4	8.3	350	10.7	12.1	18.6	3,260
150	14 +20	360	11.7	4.2	6.9	410	13.3	6.5	10.7	740	24.0	6.8	11.2	1,510	49.1	17.5	28.7	135	4.4	6.4	10.5	175	5.7	5.1	8.4	310	10.1	11.5	18.9	3,080
151	14 +29	295	15.1	6.0	10.4	340	17.4	6.0	10.4	320	16.4	6.8	11.8	955	49.0	18.8	32.7	85	4.4	5.0	8.7	155	8.0	4.9	8.5	240	12.3	9.9	17.2	1,950
Mean	14 +2	354	14.3	5.2	8.6	427	17.1	6.6	10.9	461	18.1	6.8	11.2	1,252	49.9	18.5	30.4	132	5.3	5 8	9.7	171	7.0	5.2	8.5	304	12.3	11.1	18.2	2,502
28	14 —176	260	13.0	4.5	7.8	375	18.8	6.5	11.3	355	17.8	5.5	9.6	900	49.5	16.5	28.7	110	5.5	5.9	10.2	160	8.0	5.2	9.0	270	13.5	11.1	19.3	2,000
29	14 —160	365	15.9	5.5	8.7	390	17.0	7.5	11.8	370	16.1	6.1	9.6	1,125	49.0	19.1	30.1	165	7.2	6.5	10.3	155	6.8	5.1	8.0	320	13.9	11.6	18.3	2,295
30	14 —130	610	18.3	7.3	11.1	590	17.7	7.5	11.4	520	15.6	6.5	9.9	1,720	51.6	21.3	32.4	165	5.0	6.7	10.2	170	5.1	5.1	7.8	335	10.0	11.8	17.9	3,335
31	14 —130	385	15.1	5.5	8.8	415	16.2	7.0	11.3	435	17.0	6.1	9.8	1,235	48.3	18.6	29.9	165	6.5	5.6	9.0	155	6.1	5.2	8.4	320	12.5	10.8	17.4	2,555
32	14 —92	650	16.2	7.0	9.8	620	15.5	7.0	9.8	800	20.0	8.0	11.2	2,070	51.7	22.0	30.7	240	6.0	8.4	11.7	165	4.1	5.2	7.3	405	10.1	13.6	19.0	4,005
33	14 —85	520	15.9	5.8	8.8	530	16.2	7.2	10.9	580	17.7	6.5	9.9	1,630	49.7	19.5	29.6	160	4.9	7.6	11.6	140	4.3	5.2	7.9	300	9.2	12.8	19.5	3,280
34	14 —85	515	17.5	4.8	7.6	560	19.0	7.7	12.2	435	14.8	6.3	10.0	1,510	51.2	18.8	29.9	160	5.4	6.2	9.9	150	5.1	5.7	9.1	310	10.5	11.9	18.9	2,950
35	14 —73	315	13.3	4.7	7.5	400	16.9	7.3	11.6	455	15.0	6.1	9.7	1,070	45.2	18.1	28.7	175	7.4	6.1	9.7	135	5.7	5.1	8.1	310	13.1	11.2	17.8	2,370
36	14 —57	520	17.6	7.4	10.8	410	13.9	6.4	9.3	605	20.4	7.8	11.4	1,535	51.9	21.6	31.5	195	6.6	7.0	10.2	200	6.8	5.6	8.2	395	13.3	12.6	18.4	2,960
37	14 —33	500	16.4	6.2	9.2	480	15.7	7.4	10.9	500	16.4	6.1	9.0	1,480	48.5	19.7	29.1	130	4.3	7.0	10.3	160	5.3	5.2	7.7	290	9.5	12.2	18.0	3,050
38	14 —28	460	15.3	6.0	9.2	420	13.9	6.5	10.0	640	21.2	8.5	13.0	1,520	50.4	21.0	32.2	140	4.6	6.5	10.0	175	5.6	4.8	7.4	315	10.5	11.3	17.3	3,015
39	14 —20	380	15.6	5.7	8.9	400	16.4	6.3	9.8	410	16.8	6.6	10.3	1,190	48.8	18.6	28.9	170	7.0	7.4	11.5	180	7.4	5.3	8.2	350	14.3	12.7	19.8	2,440
40	14 —10	440	15.7	5.5	8.7	485	17.3	7.0	11.0	465	16.6	6.5	10.3	1,390	49.6	19.0	30.0	135	4.8	6.3	9.9	185	6.6	5.1	8.0	320	11.4	11.4	18.0	2,800
41	14 —10	365	15.5	4.3	7.1	430	18.3	8.0	13.1	395	16.8	5.5	9.0	1,190	50.5	17.8	29.2	165	7.0	6.5	10.7	140	6.0	5.0	8.2	305	13.0	11.5	18.9	2,355
42	14 +10	540	17.4	5.3	8.7	390	12.5	5.3	8.7	540	17.4	7.5	12.4	1,470	47.3	18.0	29.8	140	4.5	5.3	8.7	190	6.1	5.5	9.1	330	10.6	10.8	17.8	3,110
43	14 +33	555	16.3	6.5	9.6	590	17.4	6.5	9.6	650	19.1	7.4	10.9	1,795	52.8	20.4	30.0	180	5.3	7.1	10.4	140	4.1	5.2	7.7	320	9.4	12.3	18.1	3,400
44	14 +76	590	18.2	7.3	10.6	530	16.4	7.8	11.3	550	17.0	7.6	11.0	1,670	51.5	22.7	32.8	125	3.9	6.3	9.1	155	4.8	5.4	7.8	280	8.6	11.7	16.9	3,240
45	14 +92	460	16.6	5.5	8.9	470	16.9	6.7	10.8	460	16.6	6.0	9.7	1,390	50.0	18.2	29.4	160	5.8	6.6	10.7	180	6.5	5.3	8.6	340	12.2	11.9	19.2	2,780
46	14 +104	280	14.0	5.0	9.0	320	16.0	5.8	10.5	320	16.0	6.1	11.0	920	46.0	16.9	30.5	120	6.0	4.9	8.8	160	8.0	5.0	9.0	280	14.0	9.9	17.8	2,000
47	14 +140	300	13.0	5.4	8.5	405	17.5	7.7	12.2	360	15.6	5.6	8.9	1,065	46.1	18.7	29.6	155	6.7	5.9	9.3	170	7.4	5.3	8.4	325	14.1	11.2	17.7	2,310
48	14 +143	485	14.4	5.5	8.3	515	15.3	7.0	10.5	585	17.4	8.4	12.7	1,585	47.1	20.9	31.5	200	5.9	5.8	8.7	165	4.9	5.6	8.4	365	10.9	11.4	17.2	3,365
49	14 +174	345	12.8	5.0	7.9	520	19.3	7.5	11.9	475	17.6	5.9	9.4	1,340	49.6	18.4	29.2	140	5.2	6.5	10.3	165	6.1	5.3	8.4	305	11.3	11.8	18.7	2,700
Mean	14 —15	447	15.6	5.7	8.9	466	16.5	7.0	10.9	491	17.2	6.7	10.4	1,404	49.4	19.4	30.2	159	5.7	6.5	10.1	164	5.9	5.2	8.1	322	11.6	11.7	18.3	2,833
Mean	14 —10	418	15.2	5.6	8.8	454	16.7	6.9	10.9	481	17.5	6.7	10.6	1,325	49.5	19.1	30.3	150	5.6	6.3	10.0	166	6.3	5.2	8.2	316	11.8	11.5	18.2	2,729
152	15 —43	380	18.6	4.0	7.1	315	15.4	6.1	10.9	305	15.0	6.1	10.9	1,000	49.0	16.2	28.9	85	4.2	5.3	9.5	155	7.6	5.4	9.6	240	11.8	10.7	19.1	2,040
153	15 —40	345	13.7	6.2	9.5	400	15.8	6.4	9.8	530	21.0	6.4	9.8	1,275	50.5	19.0	29.0	110	4.4	6.8	10.4	170	6.7	5.2	7.9	280	10.9	12.0	18.3	2,525
154	15 —35	400	15.6	5.4	9.0	385	15.0	6.8	11.3	455	17.8	6.8	11.3	1,240	48.4	19.0	31.5	55	2.2	5.4	9.0	155	6.1	5.3	8.8	210	8.2	10.7	17.7	2,560
155	15 —31	360	15.2	5.2	8.7	405	17.1	6.4	10.7	435	18.4	6.5	10.8	1,210	51.2	18.1	30.2	150	6.3	7.2	12.0	170	7.2	4.9	8.2	320	13.5	12.1	20.2	2,365
156	15 —25	300	13.2	4.8	8.3	430	18.9	6.1	10.5	345	15.1	6.1	10.5	1,075	47.2	17.0	29.4	140	6.1	6.1	10.5	165	7.2	5.4	9.3	305	13.4	11.5	19.9	2,280
157	15 —14	340	14.2	5.8	9.6	395	16.5	6.6	10.9	480	20.1	7.0	11.6	1,215	50.8	19.4	32.0	125	5.2	5.8	9.6	155	6.5	5.2	8.6	280	11.7	11.0	18.2	2,390
158	15 —8	325	13.5	5.8	9.5	395	16.5	6.0	9.9	415	17.3	7.9	13.0	1,135	47.3	19.7	32.4	155	6.5	5.8	9.5	165	6.9	5.0	8.2	320	13.3	10.8	17.8	2,400
159	15 0	375	13.4	5.3	8.7	360	12.9	6.0	9.8	515	18.4	6.0	9.8	1,250	44.6	17.3	28.4	185	6.6	5.7	9.3	175	6.3	5.3	8.7	360	12.4	11.0	18.0	2,800
160	15 +2	400	12.7	5.0	7.8	580	16.8	8.0	12.4	590	18.7	7.1	11.0	1,520	48.1	20.1	31.2	175	5.5	6.6	10.3	185	5.9	5.4	8.4	360	11.4	12.0	18.6	3,160
161	15 +9	390	14.7	6.0	9.7	340	12.9	6.0	9.7	530	20.0	6.4	10.3	1,260	47.6	18.4	29.7	140	5.3	6.0	9.7	170	6.4	5.2	8.4	310	11.7	11.2	18.1	2,645
162	15 +11	460	15.3	5.5	8.8	445	14.8	6.5	10.4	650	21.6	7.5	12.0	1,555	51.7	19.5	31.2	150	5.0	6.6	10.5	180	6.0	5.5	8.8	330	11.0	12.1	19.3	3,010
163	15 +22	375	13.0	4.8	7.7	525	18.3	7.9	12.7	590	20.5	6.7	10.8	1,480	51.5	19.4	31.3	140	4.9	6.7	10.8	170	5.9	5.1	8.2	310	10.8	11.8	19.0	2,875
164	15 +22	360	11.3	4.5	7.1	635	19.9	7.6	11.9	695	21.8	8.1	12.7	1,690	53.0	20.2	31.7	150	4.7	6.7	10.5	180	5.6	5.3	8.3	330	10.3	12.0	18.8	3,190
165	15 +24	460	14.3	5.4	8.4	435	13.5	6.7	10.5	685	21.3	6.8	10.6	1,580	49.1	18.9	29.5	175	5.4	7.6	11.9	185	5.8	5.4	8.4	360	11.2	13.0	20.3	3,220
166	15 +25	440	14.0	5.4	8.6	495	15.7	6.5	10.3	795	25.2	7.7	12.2	1,730	54.8	19.6	31.1	145	4.6	7.1	11.3	165	5.2	5.4	8.6	310	9.8	12.5	19.8	3,155
167	15 +30	390	16.3	6.0	9.7	435	18.1	7.0	11.3	385	16.0	6.4	11.1	1,210	50.4	19.4	31.3	145	6.0	6.5	9.0	160	6.7	5.2	8.4	305	12.7	10.8	17.4	2,400
168	15 +57	490	16.8	6.2	9.5	445	14.4	6.0	9.2	500	16.1	6.2	9.5	1,435	46.3	18.4	28.2	140	4.5	6.6	10.1	175	5.7	5.4	8.3	315	10.2	12.0	18.4	3,100
169	15 +61	480	19.8	6.2	10.2	365	15.0	5.6	9.2	370	15.2	6.6	10.9	1,215	50.0	18.4	30.3	130	5.4	6.2	10.2	170	7.0	5.0	8.2	300	12.4	11.2	18.4	2,430
Mean	15 +4	389	14.7	5.4	8.8	430	16.0	6.6	10.6	515	18.8	6.8	11.1	1,338	49.5	18.8	30.4	139	5.2	6.3	10.2	170	6.4	5.3	8.6	308	11.5	11.6	18.7	2,697

50	15	—157	470	14.9	5.8	8.7	500	15.8	7.0	10.5	620	19.6	7.0	10.5	1,590	50.3	19.8	29.8	175	5.5	6.7	10.1	185	5.9	5.3	8.0	360	11.4	12.0	18.1	3,160
51	15	—138	380	14.7	5.5	8.8	415	16.1	6.7	10.7	490	19.0	7.0	11.2	1,285	49.8	19.2	30.7	100	3.9	5.5	8.8	140	5.4	5.3	8.5	240	9.3	10.8	17.3	2,580
52	15	—135	410	12.7	5.1	7.5	610	18.9	8.3	12.3	560	17.3	6.2	9.2	1,580	48.9	19.6	29.0	150	4.6	6.4	9.5	190	5.9	5.6	8.3	340	10.5	12.0	17.8	3,230
53	15	—85	680	19.5	7.6	11.3	450	12.7	6.4	9.5	710	20.1	7.9	11.7	1,840	52.1	21.9	32.4	160	4.5	7.0	10.4	210	5.9	5.2	7.7	370	10.5	12.2	18.1	3,530
54	15	—30	470	16.4	6.0	9.2	515	17.9	7.4	11.3	545	19.0	7.5	11.5	1,530	53.3	20.9	32.1	130	4.5	5.6	8.6	150	5.2	5.1	7.8	260	9.8	10.7	16.4	2,870
55	15	—27	600	17.0	6.6	9.5	615	17.4	8.0	11.5	665	18.8	7.3	10.5	1,880	53.3	21.9	31.6	190	5.4	6.8	9.8	180	5.1	5.1	7.3	370	10.5	11.9	17.1	3,530
56	15	—26	380	15.1	5.0	8.0	440	17.5	7.5	12.0	450	17.9	6.5	10.4	1,270	50.4	19.0	30.4	105	4.2	5.3	8.5	145	5.8	5.2	8.3	250	9.9	10.5	16.8	2,520
57	15	0	900	24.1	10.5	14.7	540	13.7	7.5	10.5	630	16.9	7.0	9.8	2,070	54.7	25.0	35.0	190	5.1	6.8	9.5	190	5.1	5.7	8.0	380	11.0	12.5	17.5	3,730
58	15	0	535	17.0	4.8	7.3	515	16.3	7.9	12.0	580	18.4	7.7	11.7	1,630	51.7	20.4	30.9	190	6.0	7.0	10.6	180	5.7	5.0	7.6	370	11.7	12.0	18.2	3,155
59	15	0	450	15.8	6.0	8.7	380	13.4	6.5	9.4	540	19.0	7.5	10.9	1,370	48.2	20.0	29.1	130	4.6	7.5	10.9	190	6.7	5.7	8.3	320	11.3	13.2	19.2	2,840
60	15	+9	500	14.5	5.7	8.0	640	18.6	9.5	13.5	670	19.5	6.4	8.9	1,810	52.6	21.6	30.2	100	2.9	8.0	11.2	170	4.9	5.2	7.3	270	7.9	13.2	18.4	3,440
61	15	+62	580	14.8	5.3	7.7	590	15.1	7.2	10.5	750	19.1	8.3	12.1	1,920	49.0	20.8	30.3	190	4.9	6.1	8.9	150	3.8	5.3	7.7	340	8.7	11.4	16.6	3,920
62	15	+93	555	16.4	6.8	9.9	600	17.8	8.4	12.3	655	19.4	6.8	9.9	1,810	53.6	22.0	32.1	145	4.3	7.0	10.2	180	5.3	5.5	8.0	325	9.6	12.5	18.3	3,380
63	15	+112	540	14.6	6.4	9.1	625	16.9	7.5	10.6	605	16.4	7.3	10.4	1,770	48.0	21.2	30.1	144	3.9	6.8	9.7	176	4.8	5.0	7.1	320	8.7	11.8	16.7	3,690
64	15	+119	610	18.4	6.6	10.1	440	13.3	5.8	8.9	610	18.4	6.5	9.9	1,660	50.2	18.9	28.9	190	5.7	6.1	9.3	170	5.1	5.5	8.4	360	10.9	11.6	17.7	3,310
65	15	+133	500	13.2	5.3	7.8	690	18.3	7.4	10.8	735	19.4	8.3	12.2	1,925	50.9	21.0	30.8	190	5.0	7.3	10.7	165	4.4	5.3	7.8	355	9.4	12.6	18.5	3,780
66	15	+145	600	18.8	6.2	9.2	600	18.8	7.6	11.3	460	14.4	6.4	9.5	1,660	51.9	20.2	30.0	190	5.9	6.1	9.1	150	4.7	5.3	7.9	340	10.6	11.4	16.9	3,200
67	15	+180	400	15.6	5.6	8.5	430	16.8	7.8	11.8	460	18.0	5.6	8.5	1,290	50.4	19.0	28.8	160	6.3	6.6	10.0	150	5.9	5.4	8.2	310	12.1	12.0	18.2	2,560
68	15	+183	510	18.2	7.2	10.8	510	18.2	8.5	12.7	475	17.0	6.3	9.5	1,495	53.4	22.0	33.0	135	4.8	6.7	10.0	150	3.4	5.0	7.5	285	10.2	11.7	17.5	2,800
Mean	**15**	**+24**	**530**	**16.4**	**6.2**	**9.2**	**532**	**16.5**	**7.5**	**11.1**	**590**	**18.3**	**7.0**	**10.4**	**1,652**	**51.2**	**20.7**	**30.8**	**156**	**4.8**	**6.6**	**9.8**	**170**	**5.3**	**5.3**	**7.9**	**326**	**10.2**	**11.9**	**17.6**	**3,222**
Mean	**15**	**+14**	**463**	**15.6**	**5.8**	**9.0**	**482**	**16.2**	**7.1**	**10.9**	**554**	**18.6**	**6.9**	**10.7**	**1,499**	**50.4**	**19.8**	**30.6**	**148**	**5.0**	**6.5**	**10.0**	**170**	**5.8**	**5.3**	**8.2**	**317**	**10.8**	**11.7**	**18.2**	**2,967**
68	16	—183	510	18.2	7.2	10.8	510	18.2	8.5	12.7	475	17.0	6.3	9.5	1,495	53.4	22.0	33.0	135	4.8	6.7	10.0	150	5.4	5.0	7.5	285	10.2	11.7	17.5	2,800
69	16	—181	570	14.5	6.1	8.6	700	17.9	8.4	11.9	645	16.5	7.2	10.2	1,915	48.9	21.7	30.6	145	3.7	7.0	9.9	160	4.1	5.4	7.6	305	7.8	12.4	17.5	3,920
70	16	—131	630	17.8	6.7	9.9	590	16.7	7.3	10.7	670	18.9	8.0	11.8	1,890	53.4	22.0	32.4	180	4.2	7.0	10.3	190	6.2	5.0	7.4	370	10.5	12.0	17.6	3,540
71	16	—95	400	14.8	5.4	8.6	390	14.4	6.0	9.6	420	15.5	5.1	8.1	1,210	44.6	16.5	26.3	195	7.2	7.8	12.4	155	5.7	5.3	8.4	350	12.9	13.1	20.9	2,710
72	16	—82	605	15.9	5.7	7.7	650	17.1	9.0	12.2	745	19.6	7.6	10.3	2,000	52.6	22.3	30.1	170	4.5	8.4	11.4	180	4.7	5.6	7.6	350	9.2	14.0	18.9	3,805
73	16	—71	680	17.2	7.3	10.5	660	16.7	7.5	10.8	720	18.2	7.4	10.6	2,060	52.1	22.2	31.9	220	5.6	7.8	11.2	175	4.4	5.0	7.2	395	10.0	12.8	18.4	3,955
74	16	—26	530	14.7	6.5	9.0	640	17.8	8.2	11.3	740	20.5	8.3	11.5	1,910	53.0	23.0	31.8	145	4.0	7.0	9.7	160	4.4	5.3	7.3	305	8.5	12.3	17.0	3,605
75	16	+5	620	20.9	8.1	12.3	460	15.5	7.0	10.6	560	18.9	7.5	11.4	1,640	55.4	22.6	34.2	180	6.1	5.7	8.6	180	6.1	5.3	8.0	360	12.2	11.0	16.7	2,960
76	16	+24	645	20.4	7.3	10.8	525	16.6	7.9	11.6	560	17.7	6.6	9.7	1,730	54.7	21.8	32.1	120	3.2	5.3	7.8	180	6.3	5.3	7.8	300	9.5	10.6	15.6	3,160
77	16	+74	545	16.1	6.4	9.1	615	18.1	8.2	11.6	580	17.1	6.8	9.6	1,740	51.3	21.4	30.3	170	5.0	7.9	11.2	160	4.7	5.3	7.5	330	9.7	13.2	18.7	3,390
78	16	+78	430	14.4	6.2	9.2	580	14.5	7.8	11.6	540	18.1	7.4	11.0	1,550	52.0	21.4	31.7	130	4.4	6.4	9.5	150	5.0	5.4	8.0	280	9.4	11.8	17.5	2,980
79	16	+80	490	16.9	6.8	10.2	480	16.5	7.5	11.3	550	19.0	7.4	11.1	1,520	52.4	21.7	32.6	140	4.8	5.8	8.7	190	6.6	5.4	8.1	330	11.4	11.2	16.8	2,900
80	16	+101	470	17.0	6.0	9.2	510	18.5	8.0	10.2	470	17.0	7.1	10.8	1,450	52.5	21.1	32.2	125	4.5	5.8	8.9	160	5.8	5.2	7.9	285	10.3	11.0	16.8	2,760
81	16	+122	540	15.5	6.0	8.8	620	17.8	8.2	12.0	620	17.8	7.5	11.0	1,780	51.1	21.7	31.9	140	4.0	7.7	11.3	180	5.2	5.4	7.9	320	9.2	13.1	19.2	3,480
82	16	+123	460	13.8	5.8	8.6	530	15.9	6.7	10.0	695	20.8	8.1	12.1	1,685	50.4	20.6	30.7	170	5.1	7.2	10.7	185	5.5	5.5	8.2	355	10.6	12.7	18.9	3,340
83	16	+143	670	14.5	7.2	10.0	770	16.7	7.0	9.7	910	19.7	8.5	11.8	2,350	50.9	22.7	31.5	210	4.6	7.0	9.7	200	4.8	5.3	7.4	410	8.9	12.3	17.1	4,610
84	16	+161	645	17.5	7.1	10.3	635	17.2	8.0	11.7	700	19.0	7.4	10.8	1,980	53.7	22.5	32.8	165	4.5	7.4	10.8	190	5.1	5.4	7.9	355	9.6	12.8	18.7	3,690
Mean	**16**	**+8**	**555**	**16.5**	**6.6**	**9.7**	**580**	**16.8**	**7.7**	**11.3**	**624**	**18.6**	**7.3**	**10.7**	**1,759**	**51.9**	**21.6**	**31.6**	**161**	**4.7**	**6.9**	**10.1**	**173**	**5.3**	**5.3**	**7.7**	**334**	**10.0**	**12.2**	**17.8**	**3,389**
85	17	—146	400	12.9	4.8	6.9	410	13.2	6.1	8.7	640	20.6	8.6	12.3	1,450	46.6	19.5	27.9	150	4.8	6.8	9.7	150	4.8	5.0	7.1	300	9.6	11.8	16.9	3,110
86	17	—133	490	16.1	6.7	9.3	470	15.4	7.5	10.4	570	18.7	7.3	10.1	1,530	50.2	21.5	29.8	220	7.2	7.5	10.4	165	5.4	5.3	7.4	385	12.6	12.8	17.8	3,045
87	17	—92	545	15.6	6.2	9.3	620	17.8	8.0	11.9	650	18.6	7.7	11.5	1,815	52.0	21.9	32.7	162	4.6	6.0	9.0	148	4.2	5.3	7.9	310	8.9	11.3	16.9	3,490
88	17	—64	525	15.7	6.3	9.2	510	15.3	6.9	10.0	598	17.9	7.2	10.5	1,633	48.9	20.4	29.7	160	4.8	6.7	9.7	182	5.4	5.3	7.7	342	10.2	12.0	17.4	3,340
89	17	—30	665	16.7	6.7	9.6	680	17.0	7.8	11.2	740	18.5	7.2	10.3	2,085	52.3	21.7	31.1	185	4.6	7.4	10.6	165	4.1	5.3	7.6	350	8.8	12.7	18.2	3,990
90	17	+11	610	14.7	5.8	8.4	680	16.7	8.1	11.7	770	19.0	6.1	8.8	2,060	50.8	20.0	28.8	195	4.8	7.2	10.4	185	4.6	5.7	8.2	380	9.4	12.9	18.6	4,060
91	17	+15	740	18.8	6.7	9.1	660	16.8	8.7	11.8	770	19.5	8.1	10.9	2,170	55.1	23.5	31.8	160	4.1	7.1	9.6	180	4.6	5.4	7.3	340	8.6	12.5	16.9	3,940
92	17	+28	670	17.6	8.0	10.9	575	15.1	8.5	11.5	785	20.7	8.0	10.9	2,030	53.4	24.5	33.3	180	4.7	6.1	8.3	190	5.0	5.5	7.5	370	9.8	11.6	15.8	3,800
Mean	**17**	**—51**	**581**	**16.0**	**6.4**	**9.1**	**576**	**15.9**	**7.7**	**10.9**	**690**	**19.2**	**7.5**	**10.7**	**1,847**	**51.2**	**21.6**	**30.6**	**177**	**5.0**	**6.9**	**9.7**	**171**	**4.8**	**5.35**	**7.6**	**347**	**9.7**	**12.2**	**17.3**	**3,597**
93	18	—90	690	17.3	7.7	10.5	740	18.5	9.2	12.5	690	17.3	8.1	11.1	2,120	53.0	25.0	34.1	210	5.3	7.4	10.1	190	4.8	5.1	7.0	400	10.0	12.5	17.1	4,000
94	19	—7	620	18.8	7.0	10.8	540	16.4	7.0	10.8	580	17.6	6.4	9.8	1,740	52.8	20.4	31.4	240	7.3	8.0	12.3	180	5.5	5.4	8.3	420	12.7	13.4	20.6	3,300

subtracted, 143.1128 ounces is the weight of the calves, and one calf segment would weigh 71.5564 ounces, or 4 pounds, 7.5564 ounces.

From the ankle to the knee the volume curve rises from 17.5 to 77.5 units, or 60.0 units, while the specific gravity curve rises from 13.5 to 71.0 units, or 57.5 units. Dividing 60 by 57.5, a specific gravity of 1.04 + is obtained for the calf segment. The volume of the calf segment is 240 cubic inches, and the weight of an equal volume of water is 240 times 0.578 ounces, or 138.72 ounces. The weight of the segment would therefore be 1.04 times 138.72 ounces, or 144.2688 ounces. One calf segment would weigh 72.1344 ounces, or 4 pounds, 8.1344 ounces.

The weight of one calf was computed by subtracting the weight of the foot segment from the weight of both segments combined, and it was found that the weight of one calf was 4 pounds, 7.5564 ounces, or 0.578 ounce less than when computed direct (0.578 ounce equals the weight of 1 cubic inch). Likewise, if the weight of the calf segment as computed directly from the weight of both segments combined is subtracted, it is found that one foot weighs 1 pound, 9.5187 ounces, or 0.578 ounce less than when computed directly.

The specific gravity and weight of any desired segment can be computed as these values have been computed for the two segments mentioned. Why there should be the error of the weight of 1 cubic inch when the weight of a segment is computed directly and by subtracting the weight of the other segment from the weight of the two combined is not determined. The segment chosen need not be limited to those between such points as the ankle and knee, but could be such as one between the fifth and tenth inch in height.

APPARATUS FOR MEASURING THE VOLUME OF THE CRANIUM WITHOUT MEASURING THE VOLUME OF OTHER PARTS OF THE BODY

Since it may often be desirable to procure the volume of the cranium directly without measuring other parts of the body, the following methods have been devised, so that the volume procured will be free from any error due to the breathing of the subject.

The first method requires very little apparatus and gives the volume accurately. The subject lies on a table with his head and upper part of his shoulders projecting over the end of the table. A vessel large enough to receive the cranium is placed on a stool at the end of the table under the head of the subject. The vessel is full of water and just ready to run over. It has a lip or spout at one side so that the water that is displaced may be caught in a large graduate. The subject's head is lowered into the basin of water until the water level passes through the center of the auditory canals and across the bony process

above the eyes. In some cases it may be necessary to raise the foot of the table in order to bring the head in proper relation with the surface of the water in the basin. The volume of the cranium can be read directly from the amount of water displaced into the graduate. This method is accurate and is a good check on the volume of the cranium made by other apparatus. This method is especially useful because the apparatus is inexpensive and easily set up and used.

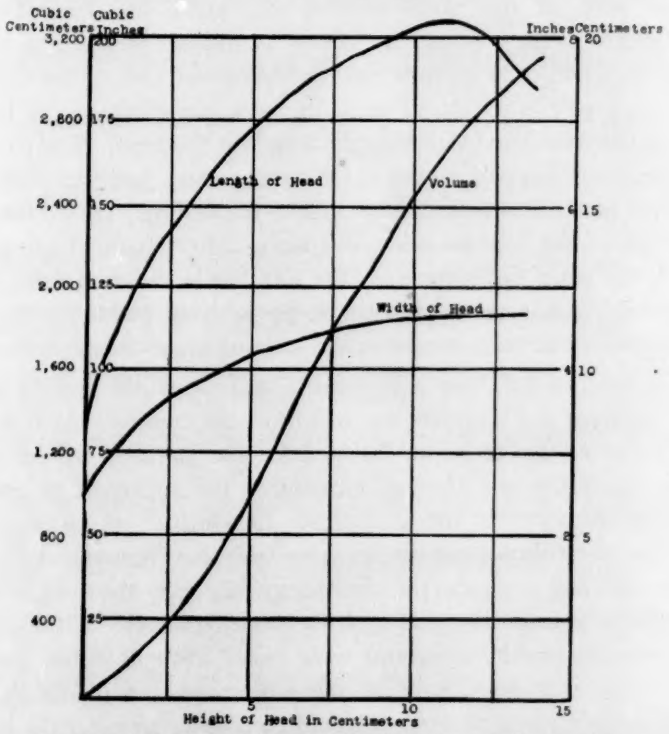

Fig. 33.—Length, width, height and volume of the cranium.

From this simple method of procuring the volume of the cranium a more elaborate apparatus has been designed which makes it possible to procure the exact volume as in the simpler method and at the same time procure a permanent record in the form of a graph similar to the one procured in the body volume apparatus and also the length, width and height of the head in detail.

Adjustable shoulder rests are placed at the end of the table so that the subject will not slip downward as the table is tilted by means of a ratchet lever to any desired slant. The table itself is mounted on a hydraulic pedestal so that the subject's head may be lowered vertically

into the tank. The tank and the measuring apparatus are similar to those used for body volume, except that there need be no compensating device, as there is no platform to be lowered into the tank. The graph board is attached to the table by gears, so that it moves to the left 1 full inch for each inch the subject or table is lowered. The cross-section of the measuring tube should be 25 square inches, so that each inch the pen rises will represent 25 cubic inches. The volume of the head is read in this scale at the left, while the height of the head appears at the bottom. Supported by fixtures attached to the wall are attached two pairs of feelers, with their lower end just at the water level. One pair is so placed as to measure the width of the head as it enters the water, and the other the length of the head. The weight of the head being lowered forces these feelers apart, and two short pens (that will pass beneath the pen recording the volume) record the width and length of the head on the same graph. The volume at any point is read in the scale for volume on the left, while the width and length of the head at any point are read in the scale in inches on the right. The height of the head is read in the scale of inches at the bottom.

It is now evident that it is possible to procure the specific gravity of the cranium and therefore the weight of the cranium. If it is possible for the subject to lie on his back on the platform of the specific gravity apparatus and after adjustment of the apparatus to lower his head into the water to the same depth to which it was submerged in measuring the volume, one can transfer the value recorded to the graph for volume and compute the specific gravity and the weight of the cranium in the same way as is done for other segments. If the platform of the specific gravity apparatus were raised about 8 inches above the water level after the weight of the subject was on it and the compensating device was released, it would be possible to lower the cranium into the water and procure the specific gravity curve in detail, so that it would be possible to compute the weight of the top inch of the head if so desired.

The apparatus and equipment for the study were provided by the Department of Education of the University of Chicago. Mr. William Larsen constructed the apparatus.

Three Consecutive Birthdays | 5 Year Group | 6 Year Group | Mean

VIII. Appendix.—*Measurements by Means of Water Displacement in Different Age Groups*

	Three Consecutive Birthdays						5 Year Group									6 Year Group					
1	1	1	1	2	2	2	200	201	1	202	203	204	Mean	Mean	Mean	205	101	1	102	207	Mean
2	.....	.....	.....	.....	.....	.....	Ital.	Pole	.....	Slav.	Pole	Ital.	Ital.	Pole	Group	Pole	.....	.....	.....	.....	Group
3	5	6+12	7—20	10+24	11	12+11	5—136	5—1	5	5+21	5+90	5+153	5+9	5+45	5+21	6—156	6—10	6+12	6+14	6+95	6—9
4	43.6	46.0	48.0	58.2	59.4	61.2	46.0	45.0	43.6	47.6	48.0	47.8	46.9	47.0	46.3	49.1	47.5	46.0	48.5	48.2	47.9
5	0.6	0.5	0.3	0.7	0.6	0.3	0.5	0.5	0.6	0.2	0.4	0.2	0.4	0.4	0.4	0.9	0.3	0.5	0.5	0.8	0.6
6	23.0	23.9	25.7	28.7	30.4	31.2	24.4	24.2	23.0	24.8	25.8	25.4	25.0	25.0	24.6	25.2	25.0	23.9	24.8	27.6	25.3
7	47.0	53.8	57.7	96.0	104.0	113.5	39.0	43.1	47.0	43.7	44.6	42.0	40.5	43.9	43.2	50.1	45.0	53.8	46.0	46.9	48.4
8	1,265	1,440	1,520	2,560	2,780	3,040	1,075	1,140	1,265	1,160	1,210	1,093	1,175	1,160	1,320	1,200	1,440	1,240	1,254	1,254	1,291
9	1.03	1.03	1.05	1.04	1.04	1.03	1.00	1.05	1.03	1.04	1.02	1.05	1.03	1.04	1.03	1.05	1.04	1.03	1.03	1.04	1.04
10	1.00	1.00	1.01	1.01	1.02	1.01	0.98	1.00	1.00	1.00	0.99	1.01	1.00	1.00	1.00	1.01	1.02	1.00	1.01	1.00	1.01
11	7.0	8.1	9.0	9.0	9.2	9.7	6.4	6.3	7.0	7.2	7.6	7.5	7.0	6.9	7.0	8.0	6.0	8.1	5.8	7.3	7.1
12	5.0	5.6	6.0	6.0	6.2	7.0	5.5	5.8	5.0	5.6	5.4	5.5	5.5	5.6	5.4	6.0	4.0	5.6	4.2	5.5	5.1
13	73	100	120	158	-160	180	65	110	73	95	73	90	73	92	84	120	63	100	58	81	84
14	87	94	98	210	205	228	53	90	87	54	68	60	57	79	69	95	127	94	108	69	99
15	21	28	33	65	70	75	23	30	21	31	25	29	26	28	27	35	30	28	40	41	35
16	1.7	1.9	2.2	2.5	2.5	2.5	2.1	2.6	1.7	2.7	2.1	2.6	2.4	2.4	2.3	2.7	2.5	1.9	3.2	3.3	2.7
17	2.0	2.2	2.4	2.8	3.0	3.2	2.0	2.0	2.0	2.4	2.6	2.1	2.1	2.3	2.2	2.6	1.8	2.2	2.0	2.4	2.2
18	4.5	4.7	5.0	4.7	5.0	5.2	4.3	4.4	4.5	5.0	5.4	4.4	4.4	4.9	4.7	5.2	3.8	4.7	4.1	4.9	4.5
19	110	115	112	200	240	290	107	85	110	129	130	126	117	108	115	125	130	115	160	79	122
20	8.7	8.0	7.4	7.8	8.5	9.5	10.0	7.5	8.7	11.1	10.7	11.4	10.7	9.1	9.9	9.5	10.8	8.0	12.9	6.3	9.5
21	10.0	10.2	10.6	13.0	13.3	13.7	10.0	9.7	10.0	11.2	10.4	10.9	10.5	10.1	10.4	10.5	11.2	10.2	11.2	9.5	10.5
22	22.6	21.9	21.9	22.0	22.2	22.3	21.5	21.3	22.6	23.4	21.5	22.7	22.1	21.4	22.1	21.0	23.4	21.9	22.9	19.4	21.7
23	299	350	360	585	730	875	215	210	290	320	235	275	245	223	259	265	360	350	280	245	300
24	23.6	24.3	23.7	22.9	26.3	28.8	20.0	18.4	23.6	27.7	19.4	24.8	22.4	18.9	22.3	20.1	30.0	24.3	22.6	19.5	23.3
25	8.0	9.4	10.4	12.8	13.1	13.7	11.5	11.3	8.0	10.4	11.4	10.9	11.2	11.4	10.9	12.3	9.5	9.4	9.8	10.6	10.3
26	18.1	20.2	21.5	21.6	21.8	22.3	24.7	24.8	18.1	21.8	23.6	22.7	23.7	24.2	22.6	24.6	19.9	20.2	20.0	21.6	21.3
27	430	493	505	850	1,040	1,240	345	325	430	480	390	430	388	358	383	425	520	493	480	365	457
28	34.0	34.2	33.2	33.2	37.4	40.4	32.1	28.5	34.0	41.4	32.2	38.7	35.4	30.4	34.5	32.2	43.3	34.2	38.7	29.1	35.5
29	20.0	21.8	23.4	28.5	29.4	30.6	23.5	23.0	20.0	24.0	24.4	23.9	23.7	23.7	23.1	25.4	22.5	21.8	23.0	22.5	23.0
30	45.3	46.9	48.4	48.3	49.0	49.8	50.5	50.5	45.3	50.2	50.4	49.8	50.2	50.5	49.5	50.8	47.1	46.9	46.9	45.9	47.5
31	200	215	235	590	580	600	175	230	200	160	190	165	170	210	187	195	220	215	200	165	199
32	15.8	14.9	15.5	23.1	20.9	19.7	16.3	20.2	15.8	13.8	15.7	14.9	15.6	18.0	16.1	14.8	18.3	14.9	16.1	13.2	15.5
33	4.8	4.6	4.5	6.5	6.5	6.6	4.1	5.3	4.8	5.2	4.6	5.0	4.6	5.0	4.8	5.3	5.5	4.6	6.5	4.0	5.2
34	10.9	9.9	9.3	11.0	10.8	10.7	8.8	11.6	10.9	10.9	9.5	10.4	9.7	10.6	10.3	10.6	11.5	9.9	13.3	8.2	10.7
35	240	230	240	400	420	400	200	185	240	160	175	150	175	180	185	215	130	230	160	188	185
36	19.0	16.0	15.8	15.6	15.1	13.2	18.6	16.2	19.0	13.8	14.5	13.5	16.1	15.4	15.9	16.3	10.8	16.0	12.9	15.0	14.2
37	5.3	5.2	5.1	6.2	6.2	6.1	5.4	5.0	5.3	5.8	5.4	4.7	5.1	5.2	5.3	5.3	6.5	5.2	5.5	5.5	5.6
38	12.0	11.2	10.6	10.6	10.3	9.9	11.6	11.0	12.0	12.1	11.2	9.8	10.7	11.1	11.3	10.6	13.6	11.2	11.2	11.2	11.6
39	185	250	260	410	420	440	180	180	185	150	250	155	168	215	183	245	110	250	160	258	205
40	14.6	17.4	17.1	16.0	15.1	14.5	16.7	15.8	14.6	12.9	20.7	14.0	15.4	18.3	15.8	18.6	9.2	17.4	12.9	20.6	15.7
41	4.8	5.6	6.0	6.5	6.5	6.5	6.0	4.7	4.8	4.8	5.9	5.5	5.8	5.3	5.3	5.6	5.0	5.6	5.5	7.4	5.8
42	10.9	12.0	12.4	11.0	10.8	10.6	12.9	10.3	10.9	10.0	12.2	11.5	12.2	11.3	11.3	11.2	10.5	12.0	11.2	15.1	12.1
43	625	695	735	1,400	1,420	1,440	555	595	625	470	615	470	585	605	555	655	460	695	520	611	588
44	49.4	48.3	48.4	54.7	51.1	47.4	51.6	52.2	49.4	40.5	50.8	42.3	47.0	51.5	47.8	49.6	38.3	48.3	41.9	48.7	45.4
45	14.9	15.4	15.6	19.2	19.2	19.2	15.5	15.0	14.9	15.8	15.9	15.2	15.4	15.5	15.4	16.2	17.0	15.4	17.5	16.9	16.6
46	33.7	33.1	32.3	32.6	32.0	31.2	33.3	33.0	33.7	33.1	32.9	31.7	32.5	33.0	33.0	32.4	35.6	33.1	35.7	34.5	34.3
47	60	90	110	150	160	180	60	80	60	80	70	80	70	75	72	100	70	90	90	110	92
48	4.7	6.3	7.2	5.9	5.8	5.9	5.6	7.0	4.7	6.9	5.8	7.2	6.4	6.4	6.2	7.6	5.8	6.3	7.3	8.8	7.2
49	4.3	4.3	4.3	5.8	5.9	6.2	3.0	3.0	4.3	3.7	3.5	4.2	3.6	3.3	3.5	3.9	4.3	4.3	4.1	4.6	4.2
50	9.7	9.2	8.9	9.8	9.8	10.1	6.5	6.6	9.7	7.7	7.2	8.8	7.7	6.9	7.8	7.8	9.0	9.2	8.4	9.4	8.8
51	150	162	170	160	160	180	115	140	150	130	135	130	123	138	133	140	150	162	150	170	154
52	11.8	11.3	11.2	6.3	5.8	5.9	10.7	12.3	11.8	11.2	11.2	11.7	11.2	11.8	11.5	10.6	12.5	11.3	12.1	13.6	12.0
53	5.0	5.0	5.0	5.5	5.5	5.5	4.6	4.5	5.0	4.3	4.6	4.7	4.6	4.6	4.6	4.5	4.5	5.0	4.4	5.0	4.7
54	11.3	10.8	10.4	9.3	9.2	8.9	9.7	9.9	11.3	9.0	9.5	9.8	9.8	9.7	9.9	9.0	9.4	10.8	9.0	10.2	9.7
55	210	252	280	310	320	360	175	220	210	210	205	210	193	213	205	240	220	252	240	280	246
56	16.6	17.5	18.4	12.1	11.5	11.8	16.3	19.3	16.6	18.1	16.9	18.9	17.6	18.2	17.7	18.2	18.3	17.5	19.4	22.3	19.1
57	9.3	9.3	9.3	11.3	11.4	11.7	7.5	7.5	9.3	8.0	8.1	8.9	8.2	8.4	8.2	8.4	8.8	9.3	8.5	9.6	8.9
58	21.0	20.0	19.3	19.1	19.0	19.0	16.1	16.5	21.0	16.7	16.7	18.5	17.3	16.6	17.6	16.8	18.4	20.0	17.4	19.6	18.4

VIII. Appendix.—*Measurements by Means of Water Displacement in Different Age Groups*—Continued*

	7 Year Group							Twins						8 Year Group									
1	208	209	210	1	103	Mean	Mean	212	213	214	215	216	217	104	218	219	220	221	222	223	Mean	Mean	Mean
2	Pole	Irish	Pole	....	....	Pole	Group	Pole	Pole	Pole	Pole	Pole	Pole	....	Pole	Irish	Irish	Ital.	Pole	Bohem.	Irish	Pole	Group
3	7—165	7—145	7—48	7—20	7—2	7—107	7—75	8—139	8—130	8—65	8—15	8—1	8—1	8+7	8+24	8+30	8+78	8+167	8+170	8+171	8+54	8—20	8+23
4	47.7	45.0	48.6	48.0	49.5	48.2	47.8	44.5	49.6	48.3	48.2	46.8	48.0	48.5	47.4	47.3	49.1	46.0	49.3	49.9	48.2	47.8	47.9
5	0.3	0.4	0.6	0.3	0.5	0.5	0.4	0.2	0.4	0	0.2	0.2	0.6	0.5	0.6	0.5	0.4	0.7	0.3	0.5	0.5	0.3	0.4
6	26.1	23.9	24.5	25.7	27.0	25.3	25.4	23.3	26.6	25.1	26.5	26.6	27.4	26.3	26.9	25.0	25.7	25.6	25.5	26.4	25.4	26.0	25.9
7	48.2	44.3	59.4	57.7	57.0	53.8	53.3	40.0	59.6	47.2	51.7	55.1	56.0	58.3	50.4	49.7	52.3	47.6	53.2	55.6	51.0	51.6	52.1
8	1,270	1,170	1,560	1,520	1,540	1,415	1,412	1,040	1,520	1,225	1,320	1,470	1,455	1,560	1,320	1,280	1,400	1,240	1,385	1,480	1,340	1,342	1,361
9	1.05	1.05	1.05	1.05	1.03	1.05	1.05	1.07	1.09	1.07	1.08	1.04	1.07	1.04	1.06	1.08	1.03	1.06	1.06	1.04	1.06	1.07	1.06
10	1.00	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.04	1.01	1.04	1.00	1.02	1.01	1.02	1.03	1.00	1.01	1.02	0.99	1.02	1.02	1.02
11	7.8	7.6	8.4	9.0	6.0	8.1	7.8	8.0	8.5	7.5	7.4	9.0	9.2	7.0	8.5	7.5	8.0	7.9	8.3	7.3	7.8	8.3	8.0
12	5.6	5.9	6.2	6.0	4.5	5.9	5.6	5.1	6.6	5.8	5.8	6.4	7.3	6.0	5.9	6.4	5.8	5.5	6.2	5.8	6.1	6.1	6.0
13	130	100	130	120	71	130	110	120	140	140	120	110	135	82	115	120	100	130	135	160	110	127	124
14	96	58	106	98	119	101	95	65	128	92	94	80	98	123	72	68	70	102	88	140	69	90	94
15	30	32	52	33	42	41	38	21	30	34	33	32	36	46	30	40	42	22	28	36	41	31	33
16	2.4	2.7	3.3	2.2	2.7	2.9	2.7	2.0	2.0	2.8	2.5	2.2	2.5	3.0	2.3	3.1	3.0	1.8	2.0	2.4	3.1	2.3	2.4
17	2.2	2.0	2.4	2.4	2.0	2.3	2.2	2.4	2.7	2.3	1.8	2.4	2.4	2.2	2.2	2.7	2.6	2.4	2.4	2.6	2.7	2.3	2.4
18	4.6	4.4	4.9	5.0	4.0	4.8	4.6	5.4	5.4	4.8	3.7	5.1	4.9	4.5	4.6	5.6	5.3	5.1	4.8	5.2	5.5	4.8	5.0
19	90	88	148	112	130	119	114	61	140	96	132	98	104	140	125	100	108	68	92	129	104	106	107
20	7.1	7.5	9.5	7.4	8.4	8.3	8.0	5.9	9.2	7.9	10.0	6.7	7.1	8.0	9.5	7.8	7.7	5.5	6.6	8.7	7.8	7.9	7.7
21	10.4	9.4	11.2	10.6	12.0	10.8	10.7	10.3	11.2	10.4	11.2	10.0	9.6	11.6	10.8	9.7	11.0	9.8	11.0	10.8	10.4	10.6	10.6
22	21.7	20.7	22.3	21.9	24.0	22.3	22.2	23.0	22.4	21.5	23.1	21.3	19.8	24.1	20.8	20.3	22.2	21.0	22.2	21.4	21.3	21.8	21.8
23	250	280	310	360	448	280	330	233	335	267	255	280	275	404	265	310	375	255	325	350	343	279	302
24	19.7	23.9	19.9	23.7	29.1	19.8	23.3	22.4	22.0	21.8	19.3	19.0	18.9	25.9	20.1	24.2	26.8	20.6	23.3	23.6	25.5	20.9	22.1
25	10.6	10.6	11.4	10.4	10.2	11.0	10.6	10.7	10.8	11.3	10.6	9.4	10.4	10.7	10.4	11.4	12.1	10.1	11.0	11.7	11.8	10.6	10.8
26	22.1	23.3	23.2	21.5	20.4	22.7	22.1	23.9	21.6	23.4	21.9	20.0	21.4	21.8	21.7	23.8	24.4	21.6	22.2	23.2	24.1	22.0	22.4
27	370	400	510	505	620	440	481	315	505	397	420	410	415	590	420	450	525	345	443	515	488	416	442
28	29.1	34.2	32.7	33.2	40.3	30.9	34.4	30.3	33.2	32.4	31.8	27.9	28.5	37.8	31.8	35.2	37.5	27.8	32.0	34.8	36.4	31.0	32.4
29	23.2	22.0	25.0	23.4	24.2	24.1	23.6	23.4	24.7	24.0	23.6	21.8	22.4	24.5	22.6	23.8	25.7	22.3	24.4	25.1	24.8	23.4	23.7
30	48.3	48.5	50.8	48.4	48.4	49.6	48.9	52.3	49.4	49.7	48.8	46.4	46.1	50.0	47.1	49.8	51.9	47.8	49.2	49.8	50.9	48.6	49.1
31	160	130	340	235	200	250	213	140	215	171	200	200	235	270	190	165	160	190	212	230	163	195	198
32	12.6	11.1	21.8	15.5	13.0	17.2	14.8	13.5	14.1	14.0	15.2	13.6	16.2	16.7	14.4	12.9	11.4	15.3	15.3	15.5	12.2	14.5	14.5
33	4.8	3.5	6.0	4.5	3.8	5.4	4.5	3.6	4.2	4.3	4.2	4.1	5.2	4.5	4.7	3.6	3.1	3.8	4.3	4.9	3.4	4.3	4.2
34	10.0	7.7	12.2	9.3	7.6	11.1	9.4	8.1	8.4	8.9	8.7	8.7	10.7	9.2	9.8	7.5	6.3	8.1	8.7	9.7	6.9	9.0	8.7
35	190	155	250	240	240	220	215	160	270	214	220	275	235	290	220	205	210	225	200	160	208	224	222
36	15.0	13.3	16.0	15.8	15.6	15.5	15.1	15.4	17.8	17.5	16.7	18.7	16.2	18.6	16.7	16.0	15.0	18.1	14.4	10.8	15.5	16.7	16.3
37	6.0	4.7	4.6	5.1	6.3	5.3	5.3	5.6	5.7	5.7	6.0	5.8	6.0	5.5	5.1	5.3	5.5	6.1	6.0	5.5	5.4	5.7	5.7
38	12.5	10.4	9.3	10.6	12.6	10.9	11.1	12.5	11.4	11.8	12.4	12.3	12.3	11.2	10.6	11.1	11.1	13.1	12.1	10.9	11.1	11.9	11.7
39	240	255	220	260	230	230	241	190	250	163	220	305	275	200	235	220	250	235	280	295	235	240	240
40	18.9	21.8	14.1	17.1	14.9	16.5	17.4	18.3	16.4	13.3	16.7	20.7	18.9	12.8	17.8	17.2	17.9	19.0	20.2	19.9	17.6	17.8	17.6
41	4.0	5.3	4.9	6.0	6.5	4.5	5.3	4.7	6.4	6.0	4.7	6.9	5.8	5.5	5.9	4.9	5.1	6.3	6.5	5.8	5.0	5.9	5.7
42	8.3	11.7	10.0	12.4	13.0	9.2	11.1	10.5	12.8	12.4	9.7	14.7	11.9	11.2	12.3	10.3	10.3	13.5	13.1	11.5	10.3	12.2	11.9
43	590	540	810	735	670	700	669	490	735	548	640	780	745	760	645	590	620	650	692	685	605	659	660
44	46.5	46.2	51.9	48.4	43.5	49.2	47.3	47.1	48.4	44.7	48.5	53.1	51.2	48.7	48.9	46.1	44.3	52.4	50.0	46.3	45.2	49.0	48.4
45	14.8	13.5	15.5	15.6	16.6	15.2	15.2	13.9	16.3	16.0	14.9	16.8	17.0	15.5	15.7	13.8	13.7	16.2	16.8	16.2	13.8	15.9	15.6
46	30.8	29.7	31.5	32.3	33.2	31.2	31.5	31.1	32.6	33.1	30.8	35.7	35.0	31.6	32.7	28,9	27.7	34.7	33.9	32.1	28.3	33.1	32.3
47	110	85	80	110	90	95	95	75	115	135	100	95	135	70	95	85	120	85	105	120	103	107	103
48	6.7	7.3	5.1	7.2	5.8	5.9	6.4	7.2	7.6	11.0	7.6	6.5	9.3	4.5	7.2	6.6	8.6	6.9	7.6	8.1	7.6	8.0	7.6
49	5.0	5.0	4.2	4.8	4.6	4.6	4.7	3.1	4.6	3.5	4.6	3.9	5.0	4.5	4.7	5.0	5.9	3.9	4.0	5.0	5.5	4.2	4.4
50	10.4	11.0	8.5	9.9	9.2	9.5	9.8	6.9	9.2	7.2	9.5	8.3	10.3	9.2	9.8	10.5	11.9	8.4	8.1	9.9	11.2	8.7	9.2
51	200	145	160	170	160	180	167	160	165	145	160	185	160	140	160	155	135	160	145	160	145	160	156
52	15.7	12.4	10.3	11.2	10.4	13.0	12.0	15.4	10.9	11.8	12.1	12.6	11.0	9.0	12.1	12.1	9.6	12.9	10.5	10.8	10.9	12.1	11.6
53	5.0	4.9	4.5	4.5	4.6	4.8	4.7	4.3	4.4	4.8	5.3	4.5	4.2	4.5	5.0	5.2	4.2	4.3	4.4	4.1	4.7	4.6	4.6
54	10.4	10.8	9.1	9.3	9.2	9.8	9.8	9.6	8.8	9.9	11.0	9.6	8.6	9.2	10.4	10.9	8.5	9.2	8.9	8.1	9.7	9.6	9.4
55	310	280	240	280	250	275	262	235	280	280	260	280	295	210	255	240	255	245	250	280	248	267	259
56	24.4	19.7	15.4	18.4	16.2	20.0	18.8	22.6	18.4	22.9	19.7	19.0	20.3	13.5	19.3	18.8	18.2	19.8	18.1	18.9	18.5	20.0	19.2
57	10.0	9.9	8.7	9.3	9.2	9.4	9.4	7.4	9.0	8.3	9.9	8.4	9.2	9.0	9.7	10.2	10.1	8.2	8.4	9.1	10.2	8.8	9.0
58	20.8	21.8	17.7	19.3	18.4	19.3	19.6	16.6	18.0	17.2	20.5	17.9	18.9	18.4	20.2	21.3	20.4	17.6	16.9	18.1	20.9	18.3	18.6

VIII. Appendix.—*Measurements by Means of Water Displacement in Different Age Groups*—Continued*

	9 Year Group																						
1	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238	239	240	241	242	243	244	245	246
2	Pole	Pole	Pole	Pole	Pole	Pole	Pole	Pole	Pole	Pole	Pole	Pole	Pole	Pole	Pole	Pole	Pole	Pole	Pole	Pole	Pole	Pole	Pole
3	9—1	9—2	9—3	9—4	9—5	9—6	9—7	9—8	9—9	9—10	9—11	9—12	9—13	9—14	9—15	9—16	9—17	9—18	9—19	9—20	9—21	9—22	9—23
4	49.2	49.2	49.2	49.2	49.2	49.2	49.2	49.2	49.2	49.2	49.2	49.2	49.2	49.2	49.2	49.2	49.2	49.2	49.2	49.2	49.2	49.2	49.2
5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
6	25.3	25.3	25.3	25.3	25.3	25.3	25.3	25.3	25.3	25.3	25.3	25.3	25.3	25.3	25.3	25.3	25.3	25.3	25.3	25.3	25.3	25.3	25.3
7	53.8	53.8	53.8	53.8	53.8	53.8	53.8	53.8	53.8	53.8	53.8	53.8	53.8	53.8	53.8	53.8	53.8	53.8	53.8	53.8	53.8	53.8	53.8
8	1,415	1,415	1,415	1,415	1,415	1,415	1,415	1,415	1,415	1,415	1,415	1,415	1,415	1,415	1,415	1,415	1,415	1,415	1,415	1,415	1,415	1,415	1,415
9	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05
10	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
11	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8
12	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9
13	130	130	130	130	130	130	130	130	130	130	130	130	130	130	130	130	130	130	130	130	130	130	130
14	101	101	101	101	101	101	101	101	101	101	101	101	101	101	101	101	101	101	101	101	101	101	101
15	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41
16	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9
17	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3
18	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8
19	114	114	114	114	114	114	114	114	114	114	114	114	114	114	114	114	114	114	114	114	114	114	114
20	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
21	10.7	10.7	10.7	10.7	10.7	10.7	10.7	10.7	10.7	10.7	10.7	10.7	10.7	10.7	10.7	10.7	10.7	10.7	10.7	10.7	10.7	10.7	10.7
22	22.2	22.2	22.2	22.2	22.2	22.2	22.2	22.2	22.2	22.2	22.2	22.2	22.2	22.2	22.2	22.2	22.2	22.2	22.2	22.2	22.2	22.2	22.2
23	330	330	330	330	330	330	330	330	330	330	330	330	330	330	330	330	330	330	330	330	330	330	330
24	23.3	23.3	23.3	23.3	23.3	23.3	23.3	23.3	23.3	23.3	23.3	23.3	23.3	23.3	23.3	23.3	23.3	23.3	23.3	23.3	23.3	23.3	23.3
25	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6
26	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1
27	481	481	481	481	481	481	481	481	481	481	481	481	481	481	481	481	481	481	481	481	481	481	481
28	34.4	34.4	34.4	34.4	34.4	34.4	34.4	34.4	34.4	34.4	34.4	34.4	34.4	34.4	34.4	34.4	34.4	34.4	34.4	34.4	34.4	34.4	34.4
29	23.6	23.6	23.6	23.6	23.6	23.6	23.6	23.6	23.6	23.6	23.6	23.6	23.6	23.6	23.6	23.6	23.6	23.6	23.6	23.6	23.6	23.6	23.6
30	48.9	48.9	48.9	48.9	48.9	48.9	48.9	48.9	48.9	48.9	48.9	48.9	48.9	48.9	48.9	48.9	48.9	48.9	48.9	48.9	48.9	48.9	48.9
31	213	213	213	213	213	213	213	213	213	213	213	213	213	213	213	213	213	213	213	213	213	213	213
32	14.8	14.8	14.8	14.8	14.8	14.8	14.8	14.8	14.8	14.8	14.8	14.8	14.8	14.8	14.8	14.8	14.8	14.8	14.8	14.8	14.8	14.8	14.8
33	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
34	9.4	9.4	9.4	9.4	9.4	9.4	9.4	9.4	9.4	9.4	9.4	9.4	9.4	9.4	9.4	9.4	9.4	9.4	9.4	9.4	9.4	9.4	9.4
35	215	215	215	215	215	215	215	215	215	215	215	215	215	215	215	215	215	215	215	215	215	215	215
36	15.1	15.1	15.1	15.1	15.1	15.1	15.1	15.1	15.1	15.1	15.1	15.1	15.1	15.1	15.1	15.1	15.1	15.1	15.1	15.1	15.1	15.1	15.1
37	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3
38	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1
39	241	241	241	241	241	241	241	241	241	241	241	241	241	241	241	241	241	241	241	241	241	241	241
40	17.4	17.4	17.4	17.4	17.4	17.4	17.4	17.4	17.4	17.4	17.4	17.4	17.4	17.4	17.4	17.4	17.4	17.4	17.4	17.4	17.4	17.4	17.4
41	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3
42	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1
43	669	669	669	669	669	669	669	669	669	669	669	669	669	669	669	669	669	669	669	669	669	669	669
44	47.3	47.3	47.3	47.3	47.3	47.3	47.3	47.3	47.3	47.3	47.3	47.3	47.3	47.3	47.3	47.3	47.3	47.3	47.3	47.3	47.3	47.3	47.3
45	15.2	15.2	15.2	15.2	15.2	15.2	15.2	15.2	15.2	15.2	15.2	15.2	15.2	15.2	15.2	15.2	15.2	15.2	15.2	15.2	15.2	15.2	15.2
46	31.5	31.5	31.5	31.5	31.5	31.5	31.5	31.5	31.5	31.5	31.5	31.5	31.5	31.5	31.5	31.5	31.5	31.5	31.5	31.5	31.5	31.5	31.5
47	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95
48	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4
49	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7
50	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8
51	167	167	167	167	167	167	167	167	167	167	167	167	167	167	167	167	167	167	167	167	167	167	167
52	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0
53	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7
54	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8
55	262	262	262	262	262	262	262	262	262	262	262	262	262	262	262	262	262	262	262	262	262	262	262
56	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8
57	9.4	9.4	9.4	9.4	9.4	9.4	9.4	9.4	9.4	9.4	9.4	9.4	9.4	9.4	9.4	9.4	9.4	9.4	9.4	9.4	9.4	9.4	9.4
58	19.6	19.6	19.6	19.6	19.6	19.6	19.6	19.6	19.6	19.6	19.6	19.6	19.6	19.6	19.6	19.6	19.6	19.6	19.6	19.6	19.6	19.6	19.6

VIII. Appendix.—*Measurements by Means of Water Displacement in Different Age Groups*—Continued*

9 Year Group

	105	106	107	224	225	226	227	228	229	230	231	232	233	234	235	236	237	Mean	Mean	Mean
	.....	.....	.....	Irish	Pole	Irish	Irish	Eng.	.....	Pole	Pole	.....	.....	Pole	Pole	Pole	Hung.	Irish	Pole	Group
	9—42	9—15	9+30	9—174	9—150	9—62	9—45	9—17	9—2	9—2	9+24	9+39	9+56	9+58	9+67	9+120	9+140	9—93	9+20	9—1
	51.8	51.0	52.0	52.6	46.5	48.4	48.6	51.2	50.1	51.7	49.5	50.9	50.9	51.9	50.7	50.2	51.3	49.9	50.4	50.5
	0.4	0.4	0.5	0.1	0.3	0.3	0.6	0.4	0.2	0.3	0.5	1.4	0	0.6	0.2	0.7	0.1	0.3	0.4	0.4
	27.2	27.2	27.0	28.0	25.4	26.0	27.2	28.1	27.9	28.0	26.1	27.9	26.8	27.4	26.3	26.8	26.8	27.1	26.7	27.1
	63.9	63.7	62.5	60.3	44.6	52.0	50.5	60.4	58.1	61.1	45.7	60.8	57.5	62.9	57.0	57.5	60.7	54.3	55.3	57.6
	1,600	1,700	1,660	1,560	1,125	1,340	1,310	1,570	1,535	1,580	1,160	1,640	1,500	1,660	1,500	1,480	1,600	1,403	1,418	1,506
	1.05	1.04	1.04	1.07	1.09	1.07	1.07	1.07	1.05	1.07	1.09	1.03	1.06	1.05	1.05	1.08	1.05	1.07	1.07	1.06
	1.02	1.02	1.01	1.03	1.06	1.03	1.02	1.02	1.02	1.01	1.03	1.00	1.02	10.2	1.01	1.04	1.02	1.03	1.03	1.02
	7.2	6.5	7.0	8.4	7.8	9.0	8.9	8.9	8.0	8.3	7.6	8.5	8.0	9.3	8.6	8.9	8.2	8.8	8.4	8.2
	5.2	4.2	5.5	6.5	5.2	7.0	6.3	5.9	6.1	6.3	6.2	6.0	6.4	6.2	6.0	6.0	7.2	6.6	6.0	6.0
	110	84	110	130	90	130	135	150	105	172	140	95	120	100	140	120	110	132	127	120
	138	116	134	98	72	100	90	110	72	126	102	78	86	81	92	108	102	96	97	100
	58	42	55	50	30	36	37	37	52	34	28	68	52	48	47	27	46	41	36	44
	3.4	2.5	3.3	3.2	2.7	2.7	2.8	2.4	3.4	2.2	2.4	4.1	3.5	2.9	3.1	1.8	2.9	2.9	2.5	2.9
	2.4	2.8	2.5	2.5	1.7	2.4	2.4	2.6	2.6	2.5	2.5	2.8	2.4	3.1	2.8	2.2	2.3	2.4	2.5	2.5
	4.6	5.5	4.8	4.7	3.6	4.9	4.9	5.0	5.2	4.8	5.0	5.4	4.7	5.9	5.5	4.3	4.5	4.8	4.9	4.9
	177	168	160	110	80	114	128	113	128	106	112	102	108	127	113	151	124	117	115	125
	10.7	9.9	9.6	7.1	7.1	8.5	9.8	7.2	8.3	6.7	9.7	6.2	7.2	7.7	7.5	10.2	7.8	8.5	8.2	8.3
	12.1	11.5	12.5	11.5	9.9	11.0	10.2	10.7	10.8	11.3	10.9	11.4	12.2	11.9	11.5	11.3	11.4	10.9	11.1	11.3
	23.2	22.4	23.8	21.8	21.2	22.6	20.7	20.7	21.5	21.7	21.8	21.8	24.0	22.7	22.6	22.2	22.2	21.7	22.0	22.2
	455	415	385	380	260	305	250	340	380	391	215	330	315	445	360	304	355	312	329	346
	26.9	24.4	23.2	24.4	23.1	22.8	19.1	21.7	24.8	24.7	18.5	20.1	21.0	26.8	24.0	20.5	22.2	22.1	22.9	22.8
	12.3	10.7	12.3	11.4	10.7	11.2	11.0	11.1	10.9	12.6	11.0	10.8	11.3	11.6	12.1	11.7	12.1	11.2	11.6	11.5
	23.6	20.8	23.4	21.6	22.9	23.0	22.4	21.5	21.7	24.2	22.0	20.7	22.2	20.1	23.8	23.0	23.5	22.3	22.7	22.4
	690	625	600	540	370	455	415	490	560	531	355	500	475	620	520	482	525	470	480	515
	40.8	36.8	36.1	34.6	32.9	34.0	31.7	31.2	36.5	33.6	30.6	30.9	31.7	37.3	34.7	32.6	32.8	33.4	33.6	34.0
	28.8	25.0	27.3	25.4	22.3	24.6	23.6	24.4	24.3	26.4	24.4	25.0	25.9	26.6	26.4	25.2	25.8	24.5	25.2	25.3
	51.3	48.6	52.0	48.2	47.6	50.5	48.0	47.3	48.3	50.8	48.8	47.8	50.9	50.7	51.9	49.5	50.2	48.9	49.9	49.6
	190	260	220	240	150	275	200	265	213	237	145	227	185	180	165	245	215	238	187	212
	11.2	15.3	13.3	15.4	13.3	20.5	15.3	16.9	13.9	15.0	12.5	13.8	12.3	10.8	11.0	16.6	13.4	17.1	13.2	14.1
	4.3	3.5	4.7	5.1	3.7	4.0	4.6	5.1	4.4	5.1	4.6	4.5	4.3	3.8	3.4	4.4	4.2	4.6	4.2	4.3
	8.2	6.8	9.0	9.7	7.9	8.2	9.3	9.9	8.7	9.8	9.2	8.6	8.4	7.3	6.7	8.6	8.2	9.1	8.3	8.5
	255	280	280	260	180	165	230	205	211	219	205	373	260	290	255	218	260	208	220	241
	15.1	16.5	16.9	16.7	11.6	12.3	17.6	13.1	13.7	13.9	17.7	22.7	17.3	17.5	17.0	14.7	16.3	15.5	15.4	15.9
	3.8	6.0	6.0	6.0	5.3	5.7	5.9	5.8	6.3	5.8	5.7	7.0	5.4	6.5	6.4	5.9	6.2	5.9	5.9	6.0
	11.1	11.6	11.4	11.4	11.3	11.7	12.0	11.2	12.5	11.2	11.4	13.4	10.6	12.4	12.6	11.6	12.1	11.7	11.8	11.7
	295	285	300	260	230	205	215	320	316	313	215	250	280	270	260	215	275	227	250	265
	17.5	16.8	18.2	16.7	20.4	15.3	16.4	20.4	20.6	19.8	18.5	15.2	18.7	16.3	17.3	14.5	17.2	16.1	17.8	17.6
	6.1	6.5	5.3	6.0	5.2	5.0	5.5	6.0	6.0	6.9	5.3	5.5	5.5	5.4	5.5	5.6	5.4	5.5	5.7	5.7
	11.7	12.7	10.1	11.4	11.1	10.3	11.2	11.6	11.9	13.3	10.6	10.5	10.8	10.3	10.8	11.0	10.5	11.0	11.2	11.2
	740	825	800	760	510	645	645	790	740	769	565	850	725	740	680	678	750	683	657	718
	43.8	48.5	48.2	48.7	45.3	48.1	49.2	50.3	48.2	48.7	48.7	51.8	48.3	44.6	45.3	45.8	46.9	48.7	46.4	47.7
	16.2	16.0	16.0	17.1	14.2	14.7	16.0	16.9	16.7	17.8	15.6	17.0	15.2	15.7	15.3	15.9	15.8	15.9	15.8	16.0
	31.0	31.1	30.5	32.4	30.3	30.2	32.5	32.8	33.2	34.2	31.2	32.5	29.9	29.9	30.1	31.2	30.7	31.7	31.2	31.4
	100	85	100	100	80	85	95	100	80	117	80	150	150	145	120	140	150	93	114	110
	5.9	5.0	6.0	6.4	7.1	6.3	7.3	6.4	5.2	7.4	6.9	9.1	10.0	8.7	8.0	9.5	9.4	6.6	7.9	7.3
	4.3	4.9	4.6	4.9	5.5	4.4	4.9	5.1	4.0	4.1	5.3	4.7	5.1	5.5	4.8	4.9	5.0	4.7	5.0	4.8
	8.2	9.5	8.8	9.3	11.8	9.0	10.0	9.9	8.0	7.9	10.6	9.0	10.0	10.5	9.4	9.6	9.7	9.4	10.0	9.5
	160	165	160	160	165	155	155	190	155	163	160	140	150	155	180	180	175	157	167	163
	9.5	9.7	9.6	10.3	14.7	11.6	11.8	12.1	10.1	10.3	13.8	8.5	10.0	9.3	12.0	12.2	10.9	11.2	12.0	11.0
	4.9	5.5	4.6	5.3	4.8	5.0	4.7	5.2	5.3	3.7	4.7	5.6	4.7	4.7	4.4	4.9	4.8	5.0	4.5	4.9
	9.4	10.7	8.8	10.1	10.3	10.3	9.6	10.1	10.5	7.1	9.4	10.7	9.2	9.0	8.6	9.6	9.3	10.0	9.0	9.6
	260	250	260	260	245	240	250	290	235	280	240	290	300	300	300	320	325	250	281	273
	15.4	14.7	15.7	16.7	21.8	17.9	19.1	18.5	15.3	17.7	20.7	17.7	20.0	18.1	20.0	21.6	20.3	17.9	20.0	18.3
	9.2	10.4	9.2	10.2	10.3	9.4	9.6	10.3	9.3	7.8	10.0	10.3	9.8	10.2	9.2	9.8	9.8	9.7	9.6	9.7
	17.6	20.2	17.5	19.4	22.0	19.3	19.5	20.0	18.5	15.0	20.0	19.7	19.3	19.4	18.1	19.3	19.1	19.4	19.0	19.1

VIII. Appendix.—*Measurements by Means of Water Displacement in Different Age Groups*—Continued*

	10 Year Group																					
1	108	109	110	111	112	2	238	239	240	241	242	243	244	245	246	247	248	249	250	251	252	253
2	.....	.....	.....	.....	.....	.....Bohem.		Pole	.....	Ital.	.....	Pole	Croet.	Slav.	Irish	Ital.	Serv.	Pole	Pole	.....	Pole	Pole
3	10—27	10—25	10—17	10—12	10+20	10+24	10—181	10—169	10—165	10—165	10—119	10—35	10—28	10—9	10+1	10+7	10+8	10+12	10+18	10+32	10+47	10+57
4	53.0	53.2	56.5	55.8	54.5	58.2	50.3	47.9	52.8	52.1	55.1	51.3	54.7	55.2	50.4	51.6	52.3	48.5	51.2	52.2	55.2	55.1
5	0.4	0.6	0.5	0.2	0.5	0.7	0.7	0.1	0.2	0	0.2	0.2	0.3	0.2	0.3	0.2	0.4	0.3	0.3	0.4	0.8	0.7
6	27.5	27.2	28.5	29.0	29.7	30.0	26.5	23.7	26.9	27.5	29.6	27.2	28.3	28.9	26.7	26.3	27.2	26.8	27.1	27.5	29.0	28.5
7	68.0	60.2	65.1	62.2	76.0	96.0	55.9	49.0	68.6	55.0	66.2	52.0	71.2	65.2	60.0	64.0	56.8	57.5	58.3	70.6	72.3	73.0
8	1,800	1,610	1,760	1,680	2,040	2,560	1,460	1,245	1,760	1,430	1,700	1,326	1,900	1,690	1,570	1,680	1,500	1,480	1,530	1,850	1,880	1,900
9	1.05	1.04	10.2	1.03	1.03	1.04	1.06	1.09	1.08	1.07	1.08	1.09	1.04	1.07	1.06	1.06	1.05	1.08	1.06	1.06	1.06	1.06
10	1.01	1.02	1.01	1.01	1.00	1.01	1.03	1.03	1.03	1.02	1.04	1.04	1.00	1.03	1.02	1.02	1.00	1.02	1.02	1.02	1.03	1.03
11	9.8	7.0	6.2	6.0	7.5	9.0	8.5	8.2	8.5	8.2	8.3	8.2	8.4	8.3	8.8	9.2	8.5	8.6	8.3	9.0	9.0	8.8
12	6.2	4.3	4.8	4.2	5.5	6.0	6.3	6.7	6.5	6.1	6.1	6.8	6.2	5.9	6.5	6.2	6.5	6.5	6.6	6.0	6.2	7.4
13	134	81	69	61	138	158	110	165	175	130	140	130	160	120	110	130	150	160	120	120	130	120
14	173	117	121	114	177	210	78	85	143	100	112	94	114	98	90	124	130	118	95	98	86	90
15	57	50	55	38	57	65	53	35	32	38	40	28	65	50	48	48	40	32	40	53	54	56
16	3.2	3.1	3.1	2.3	2.8	2.5	3.6	2.8	1.8	2.7	2.4	2.1	3.4	3.0	3.1	2.9	2.7	2.2	2.6	2.9	2.9	2.9
17	2.6	2.7	2.8	2.5	2.4	2.8	2.4	2.2	2.3	2.6	2.6	2.6	2.4	2.9	2.6	2.9	2.7	2.5	2.3	2.6	2.7	2.8
18	4.9	5.0	4.9	4.5	4.4	4.7	4.7	4.6	4.3	5.0	4.7	5.0	4.4	5.2	5.1	5.6	5.1	5.1	4.5	4.9	4.8	5.0
19	163	175	155	130	213	200	127	125	153	117	100	97	165	160	117	130	120	128	175	127	161	174
20	9.1	10.6	8.8	7.7	10.4	7.8	8.7	10.0	8.7	8.2	5.9	7.3	8.7	9.5	7.5	7.7	8.0	8.6	11.4	6.9	8.6	9.2
21	12.3	11.6	12.5	13.0	12.0	13.0	11.0	11.4	12.3	11.8	12.4	11.0	12.2	11.9	11.1	11.4	11.5	10.9	11.5	11.0	12.3	12.8
22	23.0	21.6	21.9	23.2	21.8	22.0	21.6	23.8	23.2	22.6	22.4	21.4	22.2	21.5	21.9	22.0	21.8	22.3	22.3	20.9	22.0	22.9
23	440	400	395	382	490	585	320	275	475	305	430	317	470	420	335	372	330	340	345	500	440	545
24	24.4	23.3	22.4	22.7	24.0	22.9	21.9	22.1	27.0	21.3	25.3	23.9	24.7	24.9	21.3	22.1	22.0	23.0	22.5	27.0	23.4	28.7
25	11.6	11.7	12.0	12.0	11.6	12.8	11.6	11.7	12.0	11.8	12.7	11.7	13.7	13.2	11.7	12.1	12.3	10.1	11.3	13.0	13.4	14.0
26	21.7	21.8	21.1	21.4	21.1	21.6	22.7	24.4	22.6	22.0	23.0	22.7	24.9	23.8	23.1	23.4	23.3	20.7	21.9	24.7	23.9	25.1
27	660	593	605	550	760	850	500	435	660	460	570	442	700	630	500	550	490	500	560	680	655	775
28	36.7	37.0	34.4	32.7	37.3	33.2	34.2	34.9	37.5	32.2	33.5	33.3	36.8	37.3	31.8	32.7	32.7	33.8	36.6	36.8	34.8	40.9
29	26.5	26.0	27.3	27.5	26.0	28.5	25.0	25.3	26.6	26.2	27.7	25.3	28.3	28.0	25.4	26.4	26.5	23.5	25.1	26.6	28.4	29.6
30	49.6	48.3	48.0	49.1	47.3	48.3	49.0	52.7	50.2	50.3	50.1	49.1	51.5	50.5	50.1	51.0	50.3	48.2	48.7	50.6	50.7	53.0
31	240	280	255	280	360	590	215	150	290	240	280	158	280	250	245	250	250	220	205	290	300	235
32	13.3	17.4	14.5	16.7	17.7	23.1	14.7	12.0	16.5	16.8	16.5	11.9	14.7	14.8	15.6	14.9	16.7	14.9	13.4	15.7	16.0	12.4
33	4.0	5.5	5.0	4.5	6.0	6.5	3.9	3.3	5.2	5.0	6.0	4.7	3.7	5.0	4.5	4.6	5.2	5.4	4.9	4.5	4.9	4.0
34	7.5	10.2	8.2	8.0	10.9	11.0	7.6	6.9	9.8	9.6	10.8	9.1	6.7	9.0	8.9	8.9	9.9	11.1	9.5	8.6	8.8	7.2
35	360	300	350	300	315	400	230	165	205	240	275	210	235	240	265	255	215	205	205	310	305	290
36	20.0	18.6	19.9	17.9	15.4	15.6	15.8	13.3	11.6	16.8	16.2	15.8	12.4	14.2	16.9	15.2	14.3	13.9	13.4	16.8	16.2	15.3
37	7.0	6.5	8.0	7.0	6.5	6.2	6.1	4.9	4.9	6.0	6.6	6.3	6.4	6.0	5.7	6.3	5.6	5.1	5.6	5.4	5.5	6.4
38	13.1	12.1	14.0	12.5	11.8	10.6	12.0	10.2	9.2	11.5	11.9	12.2	11.6	10.8	11.2	12.2	10.6	10.5	10.9	10.3	9.8	11.5
39	260	205	270	305	325	410	275	290	355	215	245	217	350	320	295	305	260	275	280	300	320	280
40	14.4	12.7	15.3	18.2	15.9	16.0	18.8	23.3	20.2	15.0	14.4	16.4	18.4	18.9	18.8	18.2	17.3	18.6	18.3	16.7	17.0	14.7
41	6.4	6.0	6.7	5.5	6.0	6.5	5.7	7.0	6.9	5.3	5.3	6.3	5.4	5.5	5.6	6.1	5.9	6.0	6.0	6.5	5.5	5.4
42	12.0	11.2	11.8	9.8	10.9	11.0	11.2	14.6	13.0	10.2	9.6	12.2	9.8	9.9	11.0	11.8	11.2	12.3	11.7	12.4	9.8	9.7
43	860	785	875	885	1,000	1,400	720	605	850	695	800	585	865	810	805	810	725	700	690	900	925	805
44	47.8	48.8	49.7	52.7	49.0	54.7	49.3	48.6	48.3	48.6	47.1	44.1	45.5	47.9	51.3	48.2	48.3	47.3	45.1	48.6	49.2	42.4
45	17.4	18.0	19.7	17.0	18.5	19.2	15.7	15.2	17.0	16.3	17.9	17.3	15.5	16.5	15.8	17.0	16.7	16.5	16.5	16.4	15.9	15.8
46	32.6	33.5	34.6	30.4	33.6	32.6	30.8	31.7	32.1	31.3	32.4	33.6	28.2	29.8	31.2	32.8	31.7	33.8	32.0	31.2	28.4	28.3
47	120	75	135	85	108	150	95	60	90	75	145	143	165	80	115	150	110	120	100	115	140	140
48	6.7	4.7	7.7	5.1	5.3	5.9	6.5	4.8	5.1	5.2	8.5	10.8	8.7	4.7	7.3	8.9	7.3	8.1	6.5	6.2	7.4	7.4
49	4.5	4.8	4.8	6.0	5.2	5.8	5.5	2.9	4.4	4.6	4.7	3.7	6.2	5.8	4.3	3.9	5.2	4.5	4.7	5.0	6.3	5.0
50	8.4	8.9	8.4	10.7	9.5	9.8	10.8	6.0	8.3	8.8	8.5	7.2	11.3	10.5	8.5	7.5	9.9	9.2	9.1	9.5	11.3	9.0
51	160	155	145	160	172	160	145	145	160	200	185	156	-170	170	150	170	175	160	180	155	160	180
52	8.9	9.6	8.2	9.5	8.4	6.3	9.9	11.6	9.1	14.0	10.9	11.8	8.9	10.1	9.6	10.1	11.7	10.8	11.8	8.4	8.5	9.5
53	5.0	5.0	5.2	5.5	5.3	5.5	4.8	4.6	5.0	5.0	5.0	5.2	5.0	5.1	5.2	4.5	4.3	4.3	5.2	4.6	5.4	5.4
54	9.4	9.3	9.1	9.8	9.6	9.3	9.4	9.6	9.4	9.6	9.0	10.1	9.1	9.2	10.3	8.7	8.2	8.8	10.1	8.7	9.6	9.7
55	280	230	280	245	280	310	240	205	250	275	330	299	335	250	265	320	285	280	280	270	300	320
56	15.6	14.3	15.9	14.6	13.7	12.1	16.4	16.5	14.2	19.2	19.4	22.5	17.6	14.8	16.9	19.0	19.0	18.9	18.3	14.6	16.0	16.8
57	9.5	9.8	10.0	11.5	10.5	11.3	10.3	7.5	9.4	9.6	9.7	8.9	11.2	10.8	9.5	8.4	9.5	8.8	9.9	9.6	11.7	10.4
58	17.8	18.2	17.5	20.5	19.1	19.1	20.2	15.6	17.3	18.4	17.5	17.3	20.4	19.7	18.7	16.2	18.0	18.0	19.2	18.3	20.9	18.6

VIII. Appendix.—*Measurements by Means of Water Displacement in Different Age Groups*—Continued*

10 Year Group—Continued | 11 Year Group

VIII. Appendix.—*Measurements by Means of Water Displacement in Different Age Groups*—Continued*

	10 Year Group—Continued													11 Year Group								
1	254	255	256	257	258	259	260	261	262	263	Mean	Mean	Mean	Mean	2	277	283	284	286	282	280	266
2	Pole	Ital.	Lith.	Pole	.....	.....	.....	Ger.	.....	Pole	Ital.	Pole	Group	....	.....	.....	.....	.....	.....	Dutch	Eng.	Ger.
3	10+60	10+90	10+98	10+100	10—102	10—104	10—106	10—107	10+163	10+178	10—23	10+30	10+12	11+8	11	11+8	11+46	11+59	11+64	11+45	11+31	11—118
4	54.3	52.1	51.7	54.6	59.1	54.6	51.3	53.9	59.3	56.5	51.9	52.7	53.6	56.0	59.4	55.2	56.8	54.0	52.8	59.0	52.3	51.0
5	0.7	0.4	0.6	0.8	0.6	0	0.4	0.5	0.3	0.5	0.2	0.5	0.4	0.5	0.6	0.8	0.4	0.5	0.5	0.3	0.2	0.5
6	28.1	26.3	26.8	28.6	31.0	28.2	27.2	28.3	29.7	29.9	26.7	27.7	27.9	28.5	30.4	29.3	29.2	28.5	27.6	30.6	28.3	26.3
7	63.7	64.5	62.7	63.0	78.4	70.2	60.7	71.8	89.5	73.4	61.2	62.5	66.3	69.9	104.0	69.0	100.1	63.2	71.0	81.5	68.7	56.0
8	1,660	1,720	1,580	1,620	2,040	1,850	1,540	1,825	2,350	1,960	1,610	1,622	1,734	1,857	2,780	1,800	2,640	1,640	1,860	2,180	1,820	1,460
9	1.06	1.03	1.09	1.08	1.06	1.05	1.09	1.09	1.05	1.04	1.05	1.07	1.06	1.04	1.04	1.06	1.05	1.07	1.06	1.04	1.05	1.06
10	1.03	1.00	1.05	1.03	1.03	1.02	1.04	1.04	1.02	1.01	1.01	1.03	1.02	1.01	1.02	1.02	1.02	1.02	1.02	1.01	1.02	1.02
11	8.5	8.8	8.4	8.4	9.1	9.0	8.7	8.9	10.0	8.5	8.7	8.5	8.4	7.8	9.2	8.9	10.5	9.0	8.7	9.0	8.0	7.5
12	6.8	6.5	6.4	6.5	6.4	6.4	6.1	6.7	6.8	7.1	6.3	6.7	6.2	5.7	6.2	6.0	7.5	6.1	6.1	6.7	6.6	6 0
13	120	130	140	140	160	105	175	175	150	110	130	133	132	138	160	175	160	175	140	140	140	140
14	124	117	100	110	137	96	147	155	112	88	114	99	117	161	205	160	192	166	148	154	145	146
15	35	35	40	35	55	39	39	38	61	65	40	42	46	58	70	50	78	42	70	95	60	45
16	2.1	2.0	2.5	2.2	2.7	2.1	2.5	2.1	2.6	3.3	2.5	2.6	2.7	3.2	2.5	2.8	3.0	2.6	3.8	4.4	3.3	3.1
17	3.7	2.4	2.4	2.6	2.8	2.6	2.5	2.9	2.6	2.9	2.6	2.7	2.6	2.6	3.0	2.9	2.5	2.6	2.8	3.3	2.7	2.6
18	6.7	4.6	4.6	4.7	4.7	4.8	4.8	5.3	4.4	5.1	5.1	5.0	4.9	4.5	5.0	5.2	4.4	4.8	5.3	5.6	5.1	5.0
19	165	133	110	145	170	186	128	127	219	170	127	149	149	174	240	155	222	133	175	215	160	95
20	9.9	7.7	7.0	9.0	8.3	10.1	8.3	7.0	9.3	8.7	7.9	9.2	8.6	9.5	8.6	8.6	8.4	8.1	9.4	9.9	8.8	6.5
21	11.1	11.8	11.6	12.8	13.6	12.1	11.9	12.3	12.7	12.8	11.7	11.8	11.9	13.0	13.3	12.5	13.1	12.7	11.8	13.2	11.1	11.8
22	20.2	22.5	22.2	23.1	22.8	22.2	23.0	22.6	21.3	22.5	22.4	22.3	22.3	23.1	22.2	22.3	23.0	23.3	22.1	22.3	21.1	22.9
23	350	427	430	405	490	490	335	435	625	580	368	399	421	453	730	430	785	370	525	510	455	360
24	21.1	24.8	27.2	25.0	24.0	26.5	21.8	23.8	26.6	29.6	22.7	24.4	24.1	24.5	26.3	23.9	29.7	22.6	28.2	23.4	25.0	24.7
25	12.0	13.0	12.4	12.8	13.5	13.5	11.3	11.4	15.0	14.4	12.3	12.2	12.4	13.0	13.1	12.3	14.0	12.3	13.2	13.1	12.2	11.7
26	21.8	24.8	23.7	23.1	22.6	24.7	21.9	21.0	25.2	25.3	23.6	23.2	23.0	23.1	21.8	22.0	24.6	22.6	24.8	22.1	23.2	22.7
27	550	595	580	585	715	715	502	600	905	815	535	591	590	685	1,040	635	1,085	545	770	820	675	500
28	33.1	34.6	36.7	36.1	35.0	38.6	32.6	32.9	38.5	41.6	33.2	36.1	35.3	37.1	37.4	35.3	41.1	33.2	41.4	37.6	37.1	34.2
29	26.8	27.2	26.4	28.2	29.9	28.2	25.7	26.6	30.3	30.1	26.6	26.9	27.0	28.5	29.4	27.7	29.6	27.6	27.8	29.6	26.0	26.1
30	48.7	51.8	50.5	50.9	50.1	51.6	49.7	48.9	50.8	52.8	51.0	50.5	50.1	50.6	49.0	49.5	51.9	50.6	52.2	49.9	49.5	50.7
31	260	285	220	295	345	260	268	285	295	200	258	225	268	284	590	250	415	255	250	335	240	210
32	15.7	16.6	13.9	18.2	16.9	14.1	17.4	15.6	12.6	10.2	16.1	13.9	15.4	15.4	20.9	13.9	15.7	15.5	13.4	15.4	13.2	14.4
33	6.0	5.0	4.3	5.5	5.9	4.6	4.7	5.3	4.0	3.7	4.9	4.7	4.9	5.5	6.5	5.1	5.5	5.2	4.5	5.9	4.4	4.7
34	10.9	9.5	8.2	9.9	9.9	8.4	9.1	9.7	6.7	6.5	9.3	8.9	9.0	9.7	10.8	9.1	9.7	9.5	8.4	10.0	8.4	9.1
35	270	225	250	175	340	225	263	240	430	305	240	237	269	330	420	255	360	245	270	310	340	220
36	16.3	13.1	15.8	10.8	16.7	12.2	17.1	13.2	18.3	15.6	15.0	14.5	15.5	17.7	15.1	14.2	13.6	14.9	14.5	14.2	18.7	15.1
37	6.4	4.8	5.9	5.6	6.5	5.3	5.4	5.6	7.1	7.0	5.7	5.9	6.1	6.0	6.2	5.8	5.9	6.5	6.0	7.1	7.1	5.6
38	11.6	9.1	11.3	10.1	10.9	9.7	10.4	10.3	11.9	12.3	11.3	11.0	11.2	10.6	10.3	10.4	10.4	11.9	11.3	12.0	13.5	10.9
39	315	295	270	305	350	380	267	415	370	340	272	291	302	295	420	343	440	305	250	375	300	230
40	19.0	17.2	17.1	18.8	17.2	20.5	17.3	22.7	15.7	17.3	16.8	18.2	17.5	15.7	15.1	19.1	16.7	18.6	13.4	17.2	16.5	15.8
41	6.0	5.8	5.8	6.1	7.0	6.6	7.2	7.3	6.2	5.7	5.7	6.0	6.1	6.0	6.5	6.7	5.5	5.7	5.7	5.4	5.2	4.9
42	10.9	11.0	11.1	11.0	11.7	12.1	13.9	13.4	10.4	10.0	11.0	11.4	11.3	10.7	10.8	12.0	9.7	10.5	10.7	9.1	9.9	9.5
43	845	805	740	775	1,085	865	798	940	1,095	845	770	753	839	909	1,420	848	1,215	805	770	1,020	880	660
44	50.9	46.8	46.8	47.8	50.7	46.8	51.8	51.5	46.6	43.1	47.9	46.5	48.3	48.8	51.1	47.1	46.0	49.1	41.4	46.8	48.4	45.2
45	18.4	15.6	16.0	17.2	19.4	16.5	17.3	18.2	17.3	16.4	16.3	16.6	16.1	17.5	19.2	17.6	16.9	17.4	16.2	18.4	16.7	15.2
46	33.5	29.7	30.6	31.1	32.5	30.2	33.5	33.5	29.0	28.8	31.3	31.2	31.5	31.0	32.0	31.4	29.7	31.9	30.4	31.0	31.8	29.5
47	100	140	100	100	125	120	100	140	175	130	122	115	117	108	160	142	160	110	140	140	105	120
48	6.0	8.1	6.3	6.2	6.1	6.5	6.5	7.7	7.4	6.6	7.4	7.0	6.8	5.8	5.8	7.9	6.1	6.7	7.5	6.4	5.8	8.2
49	5.1	5.2	5.1	5.6	6.0	5.0	3.7	4.6	6.2	6.0	4.6	4.9	5.0	5.1	5.9	5.7	5.5	5.3	4.6	5.8	4.4	5.4
50	9.3	9.9	9.8	10.1	10.1	9.2	7.2	8.5	10.4	10.5	8.7	9.1	9.3	9.1	9.8	10.2	9.7	9.7	8.6	9.8	8.4	10.5
51	165	180	160	160	165	150	140	145	175	170	183	164	164	155	160	175	180	180	200	160	180	
52	9.9	10.5	10.1	9.9	8.1	8.1	9.1	7.9	7.4	8.7	11.5	10.3	9.5	8.5	5.8	9.7	6.8	11.0	9.7	9.2	8.8	12.3
53	4.7	4.5	4.8	4.4	4.4	4.9	5.0	5.0	5.8	4.5	4.7	5.4	5.0	5.3	5.5	5.0	5.0	4.2	4.7	5.5	5.4	4.8
54	8.5	8.6	9.2	7.9	7.4	9.0	9.7	9.2	9.7	7.9	9.0	9.1	9.2	9.2	9.2	8.9	8.8	7.7	8.8	9.3	10.3	9.3
55	265	320	260	260	290	270	240	285	350	300	305	279	280	263	320	317	340	290	320	340	265	300
56	16.0	18.6	16.5	16.0	14.2	14.6	15.6	15.6	14.9	15.3	18.9	17.4	16.4	14.3	11.5	17.6	12.9	17.7	17.2	15.6	14.6	20.5
57	9.8	9.7	9.9	10.0	10.4	9.9	8.7	9.6	12.0	10.5	9.2	9.7	9.9	10.5	11.4	10.7	10.5	9.5	9.3	11.3	9.8	10.2
58	17.8	18.5	18.9	18.1	17.4	18.1	16.8	17.6	20.1	18.4	20.1	18.2	18.4	18.5	19.0	19.1	18.4	17.4	17.5	19.1	18.7	19.8

VIII. Appendix.—*Measurements by Means of Water Displacement in Different Age Groups*—Continued*

11 Year Group—Continued

	268	270	Mean	264	265	269	272	274	275	285	290	292	293	Mean	267	271	273	278	279	288	289	291
1.....	Irish	Irish	Irish	Ital.	Ital.	Ital.	Ital.	Ital.	Ital.	Ital.	Ital.	Ital.	Ital.	Ital.	Span.	Pole	Pole	Pole	Pole	Pole	Pole	Pole
2.....	11—95	11—85	11—90	11—129	11—121	11—90	11—84	11—40	11—6	11+60	11+149	11+154	11+160	11+5	11—113	11—85	11—45	11+9	11+29	11+93	11+147	11+150
3.....	52.7	53.2	53.0	51.5	51.3	51.1	53.6	58.4	52.1	56.7	51.0	53.8	58.1	53.8	52.8	51.4	51.8	55.1	59.5	52.4	54.0	53.2
4.....	0.3	0.2	0.3	0.1	0.7	0.5	0.4	0.6	0.3	0.2	0.3	0.7	0.3	0.4	1.1	0.1	0.6	0.7	0.8	0.1	1.0	1.1
5.....	26.8	27.9	27.4	27.2	27.3	26.4	28.5	31.0	27.8	30.1	27.8	29.0	31.1	28.6	27.9	25.9	28.9	28.8	29.7	27.7	28.6	28.9
6.....	53.8	59.5	56.2	57.5	60.7	68.0	58.0	101.2	60.2	78.2	59.7	72.7	95.9	71.2	63.5	56.9	53.8	60.2	84.6	62.2	70.3	60.4
7.....	1,450	1,620	1,535	1,500	1,580	1,780	1,540	2,600	1,620	2,080	1,560	1,900	2,520	1,868	1,630	1,450	1,420	1,540	2,220	1,590	1,900	1,548
8.....	1.03	1.02	1.03	1.06	1.06	1.06	1.04	1.08	1.03	1.04	1.06	1.06	1.05	1.05	1.08	1.09	1.05	1.08	1.05	1.08	1.02	1.08
9.....	0.99	0.99	0.99	1.04	1.03	1.03	1.01	1.03	0.99	1.02	1.02	1.03	1.02	1.02	1.03	1.03	1.01	1.04	1.02	1.04	0.99	1.03
10.....	8.0	8.8	8.4	8.3	8.5	8.6	8.1	9.6	8.5	8.9	8.3	9.1	9.5	8.7	9.3	8.2	7.5	8.5	8.7	8.5	9.4	8.7
11.....	6.5	5.6	6.1	6.1	6.8	6.7	6.3	8.0	6.4	6.9	6.5	6.8	6.1	6.7	6.2	6.4	6.4	6.5	6.5	6.1	6.2	6.0
12.....	115	120	118	110	100	155	120	250	130	100	120	120	160	137	170	175	110	120	160	120	140	152
13.....	88	132	110	104	138	172	148	235	96	112	134	148	152	144	165	137	112	122	188	122	156	169
14.....	55	63	59	47	36	38	55	44	33	60	37	52	63	47	45	38	31	32	95	42	80	41
15.....	3.8	3.9	3.9	3.1	2.3	2.1	3.6	1.7	2.0	2.9	2.4	2.7	2.5	2.5	2.8	2.6	2.2	2.1	4.3	2.6	4.2	2.6
16.....	2.6	2.9	2.8	2.9	2.2	2.6	3.0	2.5	2.4	2.7	2.6	2.3	2.3	2.6	2.7	2.5	2.2	2.3	3.2	2.2	3.3	2.7
17.....	4.9	5.4	5.1	5.6	4.2	5.0	5.6	4.2	4.6	4.8	5.1	4.2	3.9	4.7	5.0	4.9	4.2	4.1	5.3	4.2	6.0	5.0
18.....	125	117	121	113	89	147	130	196	132	200	105	138	177	143	113	117	94	108	230	113	125	137
19.....	8.6	7.2	7.9	7.5	5.6	8.3	8.4	7.5	8.1	9.6	6.7	7.3	7.0	7.6	6.9	8.1	6.6	7.0	10.4	7.1	6.6	8.9
20.....	12.1	12.3	12.2	11.3	11.2	11.8	11.6	12.2	11.3	12.7	10.9	11.7	13.0	11.8	11.7	11.3	11.1	12.3	13.8	11.8	12.0	11.8
21.....	22.8	23.0	22.9	21.9	21.5	22.9	21.5	20.7	21.6	22.3	21.3	21.5	22.3	21.8	21.7	21.9	21.2	22.0	22.9	22.5	21.8	21.7
22.....	330	370	350	330	395	435	415	715	370	550	385	480	765	484	364	375	275	365	605	415	355	346
23.....	22.8	22.8	22.8	22.0	25.0	24.4	27.0	27.5	22.8	26.4	24.7	25.3	30.4	25.6	22.3	25.9	19.4	23.7	27.3	26.1	18.9	22.4
24.....	13.3	12.3	12.8	12.2	12.4	10.7	12.8	14.0	12.0	13.0	11.8	12.8	13.9	12.6	11.8	12.9	11.8	13.4	15.4	12.5	13.7	11.7
25.....	25.1	23.0	24.1	23.6	23.8	20.7	23.7	23.7	22.9	22.9	23.0	23.5	23.8	23.2	21.9	25.1	22.5	24.0	25.5	23.8	24.9	21.5
26.....	510	550	530	490	500	620	600	955	535	810	525	670	1,005	673	522	530	400	505	930	570	560	524
27.....	35.2	34.0	34.6	32.7	32.9	34.8	39.0	36.7	33.0	38.9	33.7	35.3	39.9	35.7	32.0	36.6	28.2	32.8	41.9	35.8	29.5	33.9
28.....	28.0	27.5	27.8	26.4	25.8	25.1	27.4	28.7	25.7	28.4	25.3	26.8	29.2	26.9	26.2	26.7	25.1	28.0	32.4	26.5	29.0	26.2
29.....	52.8	51.5	52.2	51.2	49.6	48.6	50.7	48.6	49.1	49.9	49.3	49.2	50.0	49.6	48.6	51.8	47.9	50.2	53.7	50.5	52.7	48.3
30.....	190	210	200	230	225	320	160	410	235	290	240	300	335	275	253	140	255	250	305	195	320	241
31.....	13.1	13.0	13.0	15.3	14.2	18.0	10.4	15.8	14.5	13.9	15.4	15.8	13.3	14.7	15.5	9.7	18.0	16.2	13.7	12.3	16.8	15.6
32.....	4.5	4.7	4.6	3.6	4.0	6.6	4.8	5.9	4.5	5.1	4.9	5.7	4.8	5.0	5.2	3.8	5.7	4.7	5.0	3.8	4.7	5.4
33.....	8.5	8.8	8.7	7.0	7.7	12.8	8.9	10.0	8.6	9.0	9.6	10.5	8.2	9.2	9.7	7.4	10.9	8.4	8.3	7.2	8.6	9.9
34.....	190	245	218	220	335	260	225	442	250	260	205	250	440	289	200	180	220	205	305	295	335	230
35.....	13.1	15.1	14.1	14.7	21.2	14.6	14.6	17.0	15.4	12.5	13.1	13.2	17.5	15.4	12.3	12.4	15.5	13.3	13.7	18.6	17.6	14.9
36.....	4.9	5.1	5.0	5.4	7.5	4.4	5.2	5.6	6.2	6.1	4.6	6.0	6.5	5.8	5.1	5.9	6.2	6.1	6.0	5.7	5.9	6.2
37.....	9.3	9.6	9.5	10.5	14.4	8.5	9.6	9.5	11.8	10.7	9.0	11.0	11.1	10.6	9.5	11.5	11.8	10.9	10.0	10.9	10.7	11.4
38.....	310	295	303	315	240	280	320	413	280	420	310	360	360	330	355	310	250	280	380	245	425	222
39.....	21.4	18.2	19.8	21.0	15.2	15.7	20.8	15.9	17.3	20.2	19.9	18.9	14.3	17.9	21.8	21.4	17.6	18.2	17.1	15.4	22.4	14.3
40.....	6.3	5.7	6.0	6.8	5.1	5.9	6.6	6.8	5.0	6.7	6.8	5.8	5.8	6.1	6.8	6.3	6.0	6.5	6.0	5.7	5.2	5.6
41.....	11.9	10.7	11.3	13.2	9.8	11.4	12.2	11.5	9.5	11.8	13.3	10.6	9.9	11.3	12.6	12.2	11.5	11.7	10.0	10.9	9.5	10.3
42.....	690	750	720	765	800	860	705	1,265	765	970	755	910	1,135	893	808	630	725	735	990	735	1,080	693
43.....	47.6	46.3	47.0	51.0	50.6	48.3	45.8	48.7	47.2	46.6	48.4	47.9	45.0	48.0	49.6	43.4	51.1	47.7	44.6	46.2	56.8	44.8
44.....	15.7	15.5	15.6	15.8	16.6	16.9	16.6	18.3	15.7	17.9	16.3	17.5	17.1	16.9	17.1	16.0	17.9	17.3	17.0	15.2	15.8	17.2
45.....	29.6	29.0	29.3	30.6	31.9	32.8	30.7	31.0	30.0	31.5	31.8	32.1	29.3	31.2	31.7	31.1	34.2	31.0	28.2	29.0	28.7	31.7
46.....	85	140	113	120	95	150	95	225	160	120	120	180	160	143	120	105	150	140	120	95	120	123
47.....	5.9	8.6	7.3	8.0	6.0	8.4	6.2	8.7	9.9	5.8	7.7	9.5	6.3	7.7	7.4	7.2	10.6	9.1	5.4	6.0	6.3	7.9
48.....	4.4	5.0	4.7	4.8	4.2	5.0	5.3	7.0	5.2	5.1	5.0	5.7	6.2	5.4	5.2	4.1	4.7	5.7	5.6	5.6	5.2	5.1
49.....	8.3	9.4	8.9	9.3	8.1	9.7	9.8	11.9	9.9	9.0	9.8	10.5	10.6	9.9	9.7	8.0	9.0	10.2	9.3	10.7	9.5	9.4
50.....	165	180	178	125	165	150	140	155	160	180	160	140	220	160	180	185	145	160	180	190	140	208
51.....	11.4	11.1	11.3	8.3	10.4	8.4	9.1	6.0	9.9	8.7	10.3	7.4	8.7	8.7	11.0	12.8	10.2	10.4	8.1	11.9	7.4	13.4
52.....	4.9	5.4	5.2	4.6	5.4	4.6	4.7	5.0	5.8	5.5	4.7	4.5	5.9	5.1	5.4	4.7	4.7	4.8	5.3	5.2	5.0	5.8
53.....	9.3	10.1	9.7	8.9	10.4	8.9	8.7	8.5	11.1	9.7	9.2	8.3	10.1	9.4	10.0	9.1	9.0	8.6	8.8	9.9	9.1	10.7
54.....	250	320	285	245	260	300	235	380	320	300	280	320	380	302	300	290	295	300	300	285	260	331
55.....	17.2	19.8	18.5	16.3	16.5	16.9	15.3	14.6	19.8	14.4	17.9	16.8	15.1	16.4	18.4	20.0	20.8	19.5	13.5	17.9	13.7	21.4
56.....	9.3	10.4	9.9	9.4	9.6	9.6	10.0	12.0	11.0	10.6	9.7	10.2	12.1	10.4	10.6	8.8	9.4	10.5	10.9	10.8	10.2	10.9
57.....	17.6	19.5	18.6	18.2	18.5	18.6	18.5	20.3	21.0	18.6	18.9	18.7	20.7	19.2	19.7	17.1	17.9	18.8	18.1	20.6	18.5	20.1
58.....																						

VIII. Appendix.—*Measurements by Means of Water Displacement in Different Age Groups*—Continued*

12 Year Group

VIII. APPENDIX.—*Measurements by Means of Water Displacement in Different Age Groups*—Continued*

	11 Year Group—Continued					12 Year Group															
1	Mean	281	287	Mean	Mean	Mean	295	2	313	299	320	Mean	303	319	Mean	298	310	316	Mean	307	311	314
2	Pole	Serv.	Serv.	Serv.	Group	17 Ca	Jew	....	....	Cr.	Cr.	Cr.	Ger.	Ger.	Ger.	Hung.	Irish	Irish	Irish	Ital.	Ital.	Ital.
3	11+43	11+44	11+90	11+67	11+11	12+29	12—182	12+11	12+63	12—125	12+151	12+13	12—22	12+138	12+58	12—149	13+24	12+128	12+76	12+4	12+30	12+69
4	53.9	56.3	53.1	54.7	54.6	58.2	55.4	61.2	59.3	55.5	54.9	55.2	53.8	56.5	55.2	59.7	58.4	57.2	57.8	54.2	53.3	55.0
5	0.6	0.1	0.8	0.5	0.5	0.5	0.6	0.3	0.7	0.3	0.6	0.5	0.2	0.9	0.6	0.5	0.2	0.2	0.2	0.4	0.2	0.4
6	28.4	30.2	27.6	28.9	28.5	30.0	29.6	31.2	29.8	29.6	30.1	29.9	27.5	29.0	28.3	29.8	30.2	29.6	29.9	28.8	27.8	28.8
7	64.1	66.3	59.5	62.9	69.4	87.5	98.5	113.5	89.9	75.8	74.6	75.2	68.0	79.5	73.8	82.8	78.2	80.0	79.1	71.4	69.8	83.8
8	1,667	1,720	1,540	1,630	1,826	2,309	2,650	3,040	2,400	2,010	1,960	1,985	1,720	2,160	1,940	2,160	2,020	2,160	2,090	1,870	1,785	2,200
9	1.06	1.07	1.08	1.08	1.05	1.05	1.03	1.03	1.04	1.04	1.05	1.05	1.10	1.02	1.06	1.06	1.07	1.03	1.05	1.06	1.08	1.06
10	1.02	1.03	1.02	1.03	1.01	1.02	1.00	1.01	1.01	1.01	1.02	1.02	1.06	0.99	1.03	1.03	1.03	1.00	1.02	1.03	1.04	1.03
11	8.5	8.0	8.3	8.2	8.5	8.2	9.3	9.7	8.3	8.6	9.2	8.9	8.8	9.5	9.2	8.5	9.3	9.2	9.3	8.5	9.0	8.5
12	6.3	6.8	6.3	6.6	6.3	5.9	6.4	7.0	7.1	6.2	6.5	6.4	6.2	7.0	6.6	7.3	6.9	6.8	6.9	6.7	6.8	6.7
13	140	130	160	145	141	149	140	180	135	140	150	145	120	160	140	140	180	120	150	130	175	140
14	144	140	158	149	151	185	152	228	118	148	130	139	118	188	153	136	172	144	158	154	154	142
15	51	40	32	36	54	65	93	75	82	57	55	56	37	75	56	90	63	76	70	65	35	70
16	2.9	2.3	2.1	2.2	3.0	2.8	3.5	2.5	3.4	2.8	2.8	2.8	2.2	3.5	2.9	4.2	3.1	3.5	3.3	3.5	2.0	3.2
17	2.6	2.6	3.2	2.9	2.7	2.8	2.8	3.2	3.2	2.5	2.6	2.6	2.4	3.2	2.8	2.7	2.3	3.0	2.7	2.7	2.3	2.6
18	4.8	4.6	5.9	5.3	4.8	4.7	5.0	5.2	5.3	4.5	4.7	4.6	4.4	5.6	5.0	4.5	3.9	5.2	4.6	5.0	4.3	4.7
19	132	150	128	139	153	209	247	290	273	188	175	182	153	205	179	190	195	234	215	140	125	210
20	7.8	8.7	8.3	8.5	8.3	9.0	9.3	9.5	11.4	9.4	8.9	9.2	8.9	9.5	9.2	8.8	9.7	10.8	10.3	7.5	7.0	9.6
21	12.0	12.5	11.6	12.0	12.3	13.7	12.6	13.7	15.1	12.8	11.9	12.4	11.9	13.5	12.7	14.0	13.6	13.0	13.3	12.3	12.1	12.0
22	22.0	22.2	21.5	21.9	22.3	23.2	22.5	22.3	25.2	22.9	21.4	22.2	22.0	23.5	22.8	23.3	23.2	22.7	23.0	22.5	22.6	21.7
23	391	470	320	395	452	605	820	875	640	455	470	463	370	520	445	600	477	470	474	435	455	525
24	23.4	27.3	20.8	24.1	24.6	26.0	30.9	28.8	26.7	22.6	24.0	23.3	21.5	24.1	22.8	27.8	23.6	21.8	22.7	23.3	25.5	23.9
25	13.1	13.1	11.8	12.5	12.8	13.6	13.0	13.7	13.3	12.2	12.6	12.4	13.0	13.3	13.2	15.6	13.4	12.7	13.1	12.5	12.1	13.0
26	23.9	23.2	21.9	22.6	23.3	23.2	23.2	22.3	22.2	21.9	22.7	22.3	24.1	23.2	23.7	25.9	22.9	22.1	22.5	22.9	22.6	23.5
27	574	660	480	570	660	879	1,160	1,240	995	700	700	700	560	800	680	880	735	780	758	640	615	805
28	34.1	38.4	31.2	34.8	35.9	37.9	43.8	40.8	41.5	34.8	35.7	35.3	32.6	37.0	34.8	40.7	36.4	36.1	36.3	34.2	34.5	36.6
29	27.7	28.2	26.6	27.4	27.7	30.0	28.4	30.6	31.6	27.5	27.1	27.3	27.3	30.0	28.7	32.3	29.3	28.7	29.0	27.5	26.5	27.6
30	50.7	50.0	49.4	49.7	50.3	51.0	50.7	49.8	52.7	49.3	48.8	49.1	50.6	52.3	51.5	53.7	50.0	50.0	50.0	50.4	49.5	49.8
31	244	260	260	260	269	335	300	600	315	325	290	308	270	320	295	200	353	345	349	270	285	295
32	14.6	15.1	16.9	16.0	14.6	14.4	11.3	19.7	13.1	16.2	14.8	15.5	15.7	14.8	15.3	9.3	17.5	16.0	16.7	14.4	16.0	13.4
33	4.7	4.5	5.1	4.8	5.0	5.2	4.6	6.6	5.4	5.7	4.9	5.3	4.4	4.4	4.4	4.3	6.1	5.8	5.9	4.5	4.8	4.2
34	8.6	8.0	9.5	8.8	9.0	8.8	8.2	10.7	9.0	10.2	8.8	9.5	8.2	7.7	7.9	7.1	10.4	10.1	10.3	8.2	9.0	7.6
35	253	295	245	270	284	393	355	400	400	255	300	278	330	380	355	440	347	335	341	250	235	360
36	15.1	17.2	15.9	16.6	15.5	17.0	13.4	13.2	16.7	12.7	15.3	14.5	19.2	17.6	18.4	20.4	17.2	15.5	16.4	13.4	13.2	16.4
37	6.0	6.7	5.8	6.3	5.8	6.5	5.6	6.1	6.9	5.4	6.7	6.1	6.6	6.6	6.6	6.8	6.2	5.7	6.0	6.0	5.8	6.4
38	11.0	11.9	10.8	11.4	10.5	11.1	10.0	9.9	11.5	9.7	12.1	10.9	12.2	11.5	11.9	11.3	10.6	9.9	10.3	11.0	10.4	11.6
39	302	265	260	263	304	412	525	440	360	400	390	395	280	345	318	280	290	360	325	400	385	420
40	18.1	15.4	16.9	16.2	16.7	17.8	19.6	14.5	15.0	19.9	19.9	19.9	16.3	16.0	16.1	13.0	14.4	16.7	15.5	21.4	21.6	19.1
41	5.9	6.2	6.4	6.3	5.8	6.3	6.5	6.5	6.1	7.8	6.7	7.3	5.3	6.2	5.8	6.0	6.4	6.4	6.4	7.2	6.2	6.2
42	10.9	11.0	11.9	11.5	10.6	10.7	11.6	10.6	10.2	14.0	12.1	13.1	9.8	10.8	10.3	10.0	10.9	11.2	11.0	13.2	11.6	11.2
43	798	820	765	793	846	1,139	1,180	1,440	1,075	980	980	980	880	1,045	963	920	990	1,040	1,015	920	905	1,075
44	47.8	47.7	49.7	48.7	46.7	49.2	44.5	47.4	44.8	48.8	50.0	49.4	51.2	48.4	49.7	42.6	49.0	48.2	48.6	49.2	50.7	48.9
45	16.6	17.4	17.3	17.4	16.6	18.0	16.7	19.2	18.4	18.9	18.3	18.6	16.3	17.2	16.8	17.1	18.7	17.9	18.3	17.7	16.8	16.8
46	30.1	30.9	32.1	31.5	30.1	30.6	29.8	31.2	30.7	33.9	33.0	33.5	30.2	30.0	30.1	28.4	31.9	31.2	31.6	32.4	31.4	30.3
47	122	95	105	100	122	130	120	180	145	140	130	135	120	135	128	180	110	180	145	140	105	160
48	7.5	5.5	6.8	6.2	6.7	5.7	4.5	5.9	6.0	7.0	6.6	6.8	7.0	6.3	6.6	8.3	5.4	8.3	6.9	7.5	5.9	7.3
49	5.1	5.4	5.2	5.3	5.1	5.5	5.9	6.2	4.5	4.6	5.1	4.9	5.4	4.8	5.1	6.2	5.3	5.0	5.2	4.8	5.0	5.6
50	9.4	9.6	9.7	9.7	9.3	9.5	10.5	10.1	7.5	8.2	9.2	8.7	10.0	8.4	9.2	10.3	9.0	8.7	8.9	8.8	9.4	10.1
51	173	145	190	168	161	161	190	180	185	190	150	170	160	180	170	180	185	160	173	170	160	160
52	10.6	8.4	12.3	10.4	9.0	7.1	7.2	5.9	7.7	9.5	7.7	8.6	9.3	8.3	8.7	8.3	9.2	7.4	8.3	9.1	9.0	7.3
53	5.1	5.4	4.8	5.1	5.0	5.3	5.0	5.5	5.5	4.8	5.0	4.9	5.0	5.4	5.2	4.6	5.3	5.8	5.6	4.6	5.2	5.4
54	9.3	9.6	8.9	9.3	9.0	9.0	8.9	8.9	9.2	8.6	9.0	8.8	9.3	9.4	9.4	7.6	9.0	10.1	9.6	8.4	9.7	9.8
55	293	240	295	268	283	291	310	360	330	330	280	305	280	315	297	360	295	340	318	310	265	320
56	18.1	14.0	19.2	16.6	15.8	12.8	11.7	11.8	13.8	16.4	14.3	15.4	16.3	14.6	15.5	16.7	14.6	15.7	15.2	16.6	14.8	14.5
57	10.2	10.8	10.0	10.4	10.1	10.3	10.9	11.7	10.0	9.4	10.1	9.8	10.4	10.2	10.3	10.8	10.6	10.8	10.7	9.4	10.2	11.0
58	18.7	19.2	18.6	18.9	18.3	18.4	19.5	19.0	16.7	16.8	18.2	17.5	19.3	17.8	18.2	17.9	18.1	18.8	18.5	17.2	19.1	19.9

VIII. Appendix.—*Measurements by Means of Water Displacement in Different Age Groups*—Continued*

	12 Year Group																				
1	Mean	304	294	296	297	300	301	305	306	308	315	317	318	321	322	323	324	Mean	302	312	Mean
2	Ital.	Lith.	Pole	Pole	Pole	Pole	Pole	Pole	Pole	Pole	Pole	Pole	Pole	Pole	Pole	Pole	Pole	Pole	Slav.	Span.	Group
3	12+34	12—10	12—177	12—179	12—165	12—90	12—46	12—9	12—6	12+10	12+113	12+128	12+130	12+165	12+170	12+174	12+180	12+20	12—40	12+60	12+19
4	54.2	56.8	55.0	50.6	54.8	55.3	53.5	50.8	35.4	55.2	56.7	59.5	57.6	52.6	55.6	49.2	56.7	55.2	56.4	56.0	56.7
5	0.3	0.6	0.4	0.6	0.6	0.1	0.5	0.3	0.2	0.3	0	0.5	0.4	0.4	0.4	1.0	0.3	0.4	0.6	0.4	0.5
6	28.5	29.2	27.5	25.7	28.9	29.4	28.4	27.4	28.9	28.7	27.9	30.2	27.0	28.3	28.3	31.0	29.8	29.0	29.4	29.3	29.8
7	75.0	69.7	64.0	59.7	66.6	73.0	67.5	56.5	71.0	75.1	67.5	80.9	66.0	59.0	74.5	119.0	69.3	71.3	73.5	70.1	79.9
8	1,952	1,800	1,660	1,540	1,730	1,880	1,760	1,440	1,840	1,960	1,760	2,100	1,730	1,580	1,920	3,170	1,790	1,860	1,860	1,780	2,099
9	1.07	1.07	1.07	1.07	1.07	1.08	1.06	1.09	1.06	1.06	1.06	1.07	1.06	1.03	1.07	1.04	1.07	1.07	1.09	1.09	1.06
10	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.04	1.03	1.02	1.02	1.03	1.02	1.00	1.04	1.00	1.03	1.03	1.06	1.04	1.02
11	8.7	9.5	9.0	7.4	8.3	9.4	9.0	8.3	7.9	8.6	8.7	9.0	8.3	8.5	8.7	10.6	9.0	9.3	8.9	9.2	8.8
12	6.7	6.5	6.5	6.0	7.0	6.4	6.0	6.1	6.8	6.1	6.3	6.2	6.8	6.2	6.7	7.2	6.4	6.4	6.1	6.7	6.3
13	148	140	140	140	130	135	120	140	145	180	140	140	130	120	140	260	180	149	140	180	149
14	150	140	128	135	140	146	118	110	168	160	176	168	140	92	142	225	153	147	148	177	163
15	57	38	55	75	40	60	42	30	42	58	80	80	76	38	46	57	42	55	65	38	61
16	2.9	2.1	3.3	4.9	2.3	3.2	2.4	2.1	2.3	3.0	4.5	3.8	4.4	2.4	2.4	1.8	2.3	3.0	3.5	2.1	2.9
17	2.5	2.6	2.5	2.9	2.4	2.3	2.7	2.4	2.8	2.7	2.6	3.4	3.0	2.4	2.6	2.6	2.6	2.7	3.3	2.4	2.7
18	4.7	4.5	4.5	5.7	4.3	4.2	5.0	4.7	5.0	4.9	4.6	5.7	5.2	4.5	4.6	4.3	4.6	4.8	5.8	4.3	4.8
19	158	162	115	125	130	150	158	125	148	182	125	240	149	117	154	263	163	156	180	145	188
20	8.0	9.0	6.9	8.1	7.5	8.0	9.0	8.7	8.0	9.3	7.1	11.4	8.6	7.4	8.0	8.3	9.1	9.7	9.7	8.1	8.9
21	12.1	13.1	13.0	11.2	11.7	11.8	11.9	10.6	12.5	12.7	12.4	14.2	12.4	11.4	12.8	14.0	13.0	12.4	13.2	12.8	13.0
22	22.3	22.8	23.5	21.9	21.1	21.3	22.0	20.7	22.5	22.9	21.9	23.7	21.4	21.5	22.9	23.3	22.8	22.2	23.2	22.7	22.8
23	472	460	465	415	415	430	470	265	450	480	495	555	435	385	475	765	430	462	555	472	538
24	24.2	25.6	28.0	27.0	24.0	22.9	26.7	18.4	24.5	24.5	28.1	26.4	25.1	24.4	24.7	24.1	24.0	24.9	29.8	26.5	25.4
25	12.5	14.1	14.0	13.3	13.6	13.3	13.4	11.4	12.1	12.2	13.4	14.7	13.1	12.3	12.9	13.9	12.9	13.1	14.2	13.3	13.3
26	23.0	24.6	25.3	26.0	24.6	24.0	24.8	22.3	21.8	22.0	23.6	24.5	22.6	23.2	23.0	23.1	22.6	23.6	24.9	23.6	23.3
27	687	660	635	615	585	640	670	420	640	720	700	875	660	540	675	1,085	635	672	800	655	787
28	35.1	36.7	38.3	40.1	33.8	34.0	38.1	29.2	34.8	36.8	39.8	41.7	38.2	34.2	35.2	34.2	35.5	36.2	43.0	36.8	37.3
29	27.2	29.8	29.5	27.4	27.7	27.4	28.0	24.4	27.4	27.6	28.4	32.3	28.5	26.1	28.3	30.5	28.5	28.1	30.7	28.5	29.1
30	49.9	51.9	53.3	53.5	50.0	49.5	51.9	47.8	49.3	49.7	50.1	53.8	49.1	49.3	50.5	50.7	50.0	50.6	53.9	50.5	50.8
31	283	255	190	210	225	265	190	240	260	300	190	284	180	123	300	625	310	266	220	260	304
32	14.6	14.2	11.4	13.6	13.0	14.1	10.8	16.7	14.1	15.3	10.8	13.6	10.4	13.9	15.6	19.7	17.3	14.0	11.8	14.6	14.3
33	4.5	4.6	3.3	3.6	4.7	4.3	3.6	5.2	5.1	5.8	3.7	5.0	3.5	5.0	5.2	6.2	6.1	4.7	4.5	5.2	5.0
34	8.3	8.0	6.0	7.0	8.5	7.8	6.7	10.2	9.2	10.5	6.5	8.3	6.0	9.4	9.3	10.3	10.7	8.4	7.9	9.2	8.7
35	282	305	255	175	250	255	325	240	320	280	270	310	260	200	305	495	245	279	260	300	336
36	14.3	16.9	15.4	11.4	14.5	13.6	18.5	16.7	17.4	14.3	15.3	14.8	15.0	12.7	15.9	15.6	13.7	14.9	14.0	16.9	16.0
37	6.1	6.5	6.5	5.2	6.1	5.6	7.0	6.1	6.1	5.6	5.7	6.3	6.0	5.3	5.8	6.3	6.4	6.0	6.5	6.3	6.3
38	11.0	11.3	11.7	10.2	11.0	10.1	13.0	11.9	11.0	10.1	10.1	10.5	10.3	10.1	10.4	10.5	11.2	10.8	11.4	11.1	11.0
39	402	315	270	240	380	365	275	240	320	385	300	330	355	340	300	610	290	333	340	305	372
40	20.7	17.5	16.3	15.6	22.0	19.4	15.6	16.7	17.4	19.6	17.0	15.7	20.5	21.5	15.6	19.2	16.2	17.9	18.3	17.1	17.7
41	6.5	5.9	5.7	4.8	6.9	6.3	5.8	5.4	6.4	7.2	6.2	5.4	8.3	6.0	6.2	7.2	5.9	6.2	5.6	7.2	6.3
42	12.0	10.3	10.3	9.4	12.5	11.4	10.7	10.6	11.5	13.0	10.9	9.0	14.3	11.3	11.1	12.0	10.4	11.2	9.8	12.8	11.1
43	967	875	715	625	855	885	790	720	900	965	760	925	795	760	905	1,730	845	878	820	865	1,011
44	49.6	48.6	43.1	40.6	49.0	47.1	44.9	50.0	48.9	49.2	43.2	44.0	46.0	48.1	47.1	54.6	47.2	46.9	44.1	48.6	48 0
45	17.1	17.0	15.5	13.6	17.7	16.2	16.4	16.7	17.6	18.6	15.6	16.7	17.8	16.3	17.2	19.7	18.4	16.9	16.6	18.7	17.5
46	31.4	29.6	28.0	26.6	32.0	29.2	30.4	32.7	31.7	33.5	27.5	27.8	30.7	30.8	30.7	32.7	32.3	30.4	29.1	33.2	30.7
47	135	125	115	120	100	175	140	140	140	115	160	180	105	90	180	175	125	137	100	95	134
48	6.9	6.9	6.9	7.8	5.8	9.3	8.0	7.7	7.6	5.9	9.1	8.6	6.1	5.7	9.4	5.5	7.0	7.4	5.4	5.3	6.5
49	5.1	5.7	5.4	5.6	5.3	5.9	5.0	5.3	5.4	5.1	7.0	6.4	6.7	5.1	5.5	4.8	5.5	5.6	5.2	4.2	5.4
50	9.4	9.9	9.8	10.9	9.6	10.7	9.3	10.4	9.7	9.2	12.4	10.7	11.6	9.6	9.8	8.0	9.7	10.1	9.1	7.5	9.6
51	163	140	195	180	190	180	160	160	160	160	140	120	170	190	160	180	185	169	140	165	166
52	8.5	7.8	11.7	11.7	11.0	9.6	9.1	11.1	8.7	8.2	8.0	5.7	9.8	12.0	8.3	5.7	10.3	9.4	7.5	9.3	8.2
53	5.1	4.9	5.0	4.6	4.7	5.9	4.6	4.7	5.2	4.2	5.7	4.6	5.0	5.5	5.0	5.2	4.6	5.0	4.5	5.0	5.1
54	9.3	8.5	9.0	9.0	8.5	10.7	8.5	9.2	9.4	7.6	10.1	7.7	8.6	10.4	8.9	8.6	8.1	9.3	7.9	8.9	9.0
55	300	265	310	300	290	355	300	300	300	275	300	300	275	280	340	355	310	306	240	260	300
56	15.3	14.7	18.7	19.5	16.8	18.9	17.0	20.8	16.3	14.0	17.0	14.3	15.9	17.7	17.7	11.2	17.3	16.9	12.9	14.6	14.7
57	10.2	10.6	10.4	10.2	10.0	11.8	9.6	10.0	10.6	9.3	12.7	11.0	11.7	10.6	10.5	10.0	10.1	10.6	9.7	9.2	10.5
58	18.7	18.5	18.8	19.9	18.1	21.3	17.8	19.6	19.1	16.8	22.4	18.3	20.2	20.0	18.8	16.6	17.7	19.0	17.0	16.3	18.5

* KEY TO TABULATION

1. Case number: 1-99, University group; 100-163, settlement group; 200 up park group. The last group includes children from the park playgrounds in Chicago.
2. Race in cases in which both parents were of same nationality.
3. Age in years, plus or minus number of days.
4. Height in air, inches.
5. Variation in height when measured in water.
6. Sitting height, inches.
7. Weight stripped, pounds.
8. Total body volume at exhale, cubic inches.
9. Specific gravity of total body at exhale.
10. Specific gravity of total body, mean between exhale and inhale.
11. Width of chest, inches.
12. Depth of chest, inches.
13. Lung capacity, cubic inches.
14. Volume of both arms, cubic inches.
15. Feet: volume, cubic inches.
16. Feet: percentage of total body volume.
17. Feet: height, inches.
18. Feet: percentage of total body height.
19. Calf: volume, cubic inches.
20. Calf: percentage of total body volume.
21. Calf: height, inches.
22. Calf: percentage of total body height.
23. Thigh: volume, cubic inches.
24. Thigh: percentage of total body volume.
25. Thigh: height, inches.
26. Thigh: percentage of total body height.
27. Total legs: volume, cubic inches.
28. Total legs: percentage of total body volume.
29. Total legs: height, inches.
30. Total legs: percentage of total body height.
31. Loin: volume, cubic inches.
32. Loin: percentage of total body volume.
33. Loin: height, inches.
34. Loin: percentage of total body height.
35. Abdomen: volume, cubic inches.
36. Abdomen: percentage of total body volume.
37. Abdomen: height, inches.
38. Abdomen: percentage of total body height.
39. Chest: volume, cubic inches.
40. Chest: percentage of total body volume.
41. Chest: height, inches.
42. Chest: percentage of total body height.
43. Total trunk: volume, cubic inches.
44. Total trunk: percentage of total body volume.
45. Total trunk: height, inches.
46. Total trunk: percentage of total body height.
47. Neck: volume, cubic inches.
48. Neck: percentage of total body volume.
49. Neck: height, inches.
50. Neck: percentage of total body height.
51. Cranium: volume, cubic inches.
52. Cranium: percentage of total body volume.
53. Cranium: height, inches.
54. Cranium: percentage of total body height.
55. Total head: volume, cubic inches.
56. Total head: percentage of total body volume.
57. Total head: height, inches.
58. Total head: percentage of total body height.

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